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Annual Report
October 1989

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OPERATION OF RELIABILITY ANALYSIS CENTER (FY88)

IIT Research Institute

Donna R. Crossland

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, NY 13441-5700

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This is the first Annual Report for Operation of the Reliability Analysis Center, in accordance with CLIN 0002, ELIN A010, DI-S-3591A, under Contract F30602-87-C-0228. Information concerning expended effort, accrued operating cost, volumes produced, user services (and income derived from these services) and distribution of technical publications is provided for the fiscal year 1 Oct 87 to 30 Sep 88.

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PREFACE

The Reliability Analysis Center (RAC), technically managed by Rome Air Development Center (RADC), is a Department of Defense (DoD) Information Analysis Center with the express purpose of serving as a focal point for the recovery of reliability test and experience data on electronic systems and the components used therein. It is one of several DoD Information Analysis Centers, administratively managed by the Defense Logistics Agency (DLA), operating in unique, narrowly defined technical areas. Since its inception in 1968, the RAC has been operated by IIT Research Institute under contract to the United States Air Force (at its Chicago Headquarters from 1968 to 1972; at RADC, Griffiss Air Force Base, New York from 1972 through 1988; and since August 1988 at a contractor facility in Rome, New York). The RAC mission is to collect, analyze, synthesize, format and disseminate reliability information on electronic equipments/systems and on the microcircuit, discrete semiconductor and electromechanical components that make up the functional hardware. Analyzed and evaluated reliability information is disseminated through reliability compilations, handbooks, appropriate special publications and direct consulting assistance to support defense systems development and to upgrade their reliability. The RAC engineering services are made available, under service charge arrangements, directly to government agencies and contractors, enabling efficient application and utilization of the accumulated knowledge and information to specific problems.

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1.0 INTRODUCTION

This is the first Annual Report for Operation of the Reliability Analysis Center, in accordance with CLIN 0002, ELIN A010, DI-S-3591A, under Contract F30602-87-C-0228. Information concerning expended effort, accrued operating cost, volumes produced, user services (and income derived from these services) and distribution of technical publications is provided for the fiscal year 1 October 1987 to 30 September 1988.

2.0 SUMMARY OF FY-88 TECHNICAL ACCOMPLISHMENTS

2.1 Significant Accomplishments

USER RECEIPTS

The RAC collected a total of $489,342.67 in checks, purchase orders, and wire transfers during FY'88. It was distributed as follows:

Engineering Services	$ 66,111.50
Document Sales	178,858.17
Training Course Receipts	244,373.00

A total of 4,331 RAC documents were distributed during FY'88.

TRAINING COURSES

The Design Reliability Training Course was presented 11 times during FY'88. Three of the courses were "open" and eight were "on-site" course presentations.

The Statistical Process Control Training Course was presented three times during FY'88. All three of the courses were "open" presentations.

The Testability Practices Today Training Course was presented six times during FY'88. Four of the courses were "open" presentations and two were "on-site" course presentations.

A massive effort was undertaken to completely revamp the Design Reliability Training Course. This task involved updating and inputting all course material to the RAC desktop publishing system, and regenerating many tables, figures, diagrams and charts. The culmination of this project will find 99% of the training course automated for ease of change for all future course updates. The effort was 75% completed during FY'88.

DATABASES

A total of 1,002 documents were received for possible inclusion in the RAC document center. Approximately 2,000 documents were abstracted, indexed, and added to the library database.

Data acquisition personnel visited approximately 50 difference companies and government agencies in an effort to promote the RAC, established contacts, discuss data formats, and obtain data to enhance RAC databases.

A specialized mailing was conducted to collect reliability test and failure related data on optoelectronics devices in support of a new state-of-the art report entitled, "Reliability Review of Optoelectronic Devices." The data collected will be analyzed, and entered into a database for future consideration.

HANDBOOKS AND DATABOOKS

Work was completed on the following handbooks and databooks:

Microcircuit Screening Analysis - MDR-22

This 169 page publication makes fallout rate data on integrated circuits available to RAC users. This data can be used as a baseline to define typical fallout rate values as a function of device and screen stress variables. This publication covered digital, linear, interface, and memory devices. Various standard screens are analyzed, as well as screening sequences, making this data extremely useful for those who wish to: (1) Compare fallout rates from a particular process or line to industry averages, and (2) Customize screening tests to optimize the cost/benefit ratio (non-military applications).

Microcircuit Screen Data - MDR-22A

This publication contains 375 pages of detailed microcircuit screening data used to develop the analyses of MDR-22, "Microcircuit Screening Analysis." This data is made available to: (1) Perform analyses that were not presented in MDR-22 and (2) Examine unique part numbers or a specific set of test conditions.

Discrete Semiconductor Device Reliability - DSR-4

DSR-4 contains detailed field and test reliability data on a wide range of discrete semiconductor devices, liquid crystal displays, and photovoltaic cells. The data is organized to facilitate location of necessary information in a minimum of time. The data contained in DSR-4, which has been compiled from military and commercial data sources, details the nature of device failures by presenting device characteristics as well as imposing environmental and electrical stresses.

Work began on the following handbooks and databooks:

TRS-5, MIL-HDBK-338 Index - The objective of this project is to generate a technical index for MIL-HDBK-338, "Electronics Reliability Design Handbook".

Electrostatic Discharge Susceptibility Data, VZAP-2 - This publication presents electrostatic discharge susceptibility data and analysis of integrated circuits, discrete semiconductors and selected resistor types. This is an update to the 1983 RAC publication, Electrostatic Discharge Susceptibility Devices, VZAP-1.

STATE OF THE ART REPORTS

Work was completed on the following state-of-the-art report:

A Primer for DoD Reliability, Maintainability and Safety Standards - PRIM-1

This publication contains descriptive synopses of the 38 most often used military standards, specifications and handbooks dealing with reliability, maintainability and safety currently available. It provides a concise and pertinent overview of the most important military documents currently in the field. PRIM-1 provides the user with a single reference guide to the applicability and use of the

most pertinent R, M&S military documents. This publication eliminates the necessity of having to order and review each document separately to determine its applicability to a specific program.

Work also began on the following state-of-the-art reports:

Procedures for Fault Tree Analysis - This work will consist of research on current state-of-the-art in Fault Tree Analysis techniques and the development of a clear, easy to read set of procedures illuminated by real world examples and guidance relative to the procurement of such services.

Design of Experiments - The objective is to develop a statistical state-of-the-art report on Design of Experiments.

Optoelectronics - Develop a state-of-the-art report which will provide a design engineer with reliability information to guide in the selection and application of optoelectronic semiconductor devices.

RELOCATION OF THE RAC OFFICES

On 1 August 1988, the Reliability Analysis Center moved to off-base facilities at the request of the government. The move involved turning in all government owned furniture, and arranging for suitable replacements. The move was well planned in advance and arrangements were made for the transfer of telephones, the installation of new computer lines, and the orderly transition to the new facilities to be accomplished over the weekend for a minimal amount of downtime during normal duty hours.

PROMOTIONAL EFFORTS

Work was completed on updating the RAC Products and Services Catalog. The catalog was re-written and the pages are now resident on a RAC Macintosh computer. The various pages can now be updated and reproduced in-house with much greater ease. Sections in the catalog include:

- Full Service Participation Plan
- Reliability Publications
- Training Courses

- Product Fee Schedule
- Order Forms

A copy of the Products and Services Catalog is included in Appendix A.

Scott Brown & Company were hired as consultants to conduct a customer survey of RAC Newsletter customers and to provide feedback to enhance the RAC's marketing capabilities. Their expertise was also enlisted to produce a new marketing brochure to better emphasize RAC products and services. The brochure was approved and will be available for distribution during the first quarter of FY'89.

Concentrated efforts in the expansion of Statistical Process Control/Total Quality Management (SPC/TQM) capabilities. The staff was doubled in size to provide additional capabilities in the areas of:

- Computer Aided Manufacturing
- Needs Analysis
- Value Engineering

As well as broadening the base of Management and Statistical expertise necessary for TQM, software and hardware capabilities were also expanded with the additional staff.

A charter was developed and drafted for the establishment of a RAC Technical Advisory Group (TAG). The objectives of the TAG are expected to be as follows:

- to provide a broader perspective and to provide feedback to the strategic planning process for the RAC.

- to maintain and enhance the credibility of the RAC as the DoD central source for Reliability and Maintainability data and information.

- to increase the Reliability and Maintainability community's awareness of the RAC and its capabilities.

- to gain more extensive user input on specific product development needs and feedback on existing products/services.

It is anticipated that the TAG will have an approved charter, members chosen, an agenda completed, and a meeting scheduled during the first quarter of FY'89.

Four RAC Newsletters were prepared and distributed during FY'88 to over 12,000 RAC users. The feature article and subject of the Technical Brief for each issue is shown below in Figure 2-1:

ISSUE	FEATURE ARTICLE	TECHNICAL BRIEF
Oct 87	"The 80% Solution" by Steven J. Flint, Director, Reliability Analysis Center (RAC)	N/A
Feb 88	"The RAC Contribution" by Preston R. MacDiarmid, RADC RAC Program Manager	"Effects of Periodic Testing on Systems Reliability" by David Coit, Michael Rossi, and David Dekkers, RAC
May 88	"R&M 2000 Direction" by Frank S. Goodell, Brigadier General, Special Assistant for R/M, Headquarters, USAF	"Identifying and Capturing Quality Costs" by Richard Hurley, RAC
Sep 88	"Reliability: Where are the Universities?" by Professor Marvin L. Roush, Director, Center for Reliability Engineering, University of Maryland	"Reliability Growth Analysis Using AMSAA Model" by David Tyler and David Russell, RAC

FIGURE 2-1: NEWSLETTER FEATURE ARTICLES AND TECHNICAL BRIEFS

SPECIAL STUDIES

During FY'88 the RAC engineering staff was involved in 26 unique study and support projects for various DoD government agencies. Figure 2-2 shows the breakdown of those special studies within DoD.

Organization	Completed	Active	Total
Army	2	7	9
Air Force	0	12	12
Navy	0	3	3
Other Govt.	0	2	2
TOTALS	2	24	26

FIGURE 2-2: BREAKDOWN OF SPECIAL STUDIES WITHIN DOD

2.2 Problems Encountered

No significant problems were encountered.

3.0 USER PRODUCTS AND SERVICES INFORMATION

During FY'88 four issues of the RAC Newsletter were published and disseminated, each issue to over 12,000 individuals. A copy of the September RAC Newsletter is included in Appendix B. Twelve separate training course flyers were distributed to over 12,000 individuals. Product flyers were distributed to over 12,000 individuals on Microcircuit Screening Analysis (MDR-22) and Microcircuit Screening Data (MDR-22A), on Discrete Semiconductor Device Reliability (DSR-4) and on A Primer for DoD Reliability, Maintainability and Safety Standards (PRIM-1)

There were a total of 363 information packages mailed as a result of phone inquiries, magazine advertisements, requests from customers and requests from individuals to be placed on the RAC mailing listing.

3.1 User Services

There were a total of 650 bibliographic and 317 technical (gratis) inquiries responded to during FY'88.

A project was completed and a final report delivered to CHEMFAB for a part stress reliability prediction on a Radome Inflation System. Total value was $2,600.

A project was completed and a final report delivered to Lifeline Systems for performing a part stress reliability prediction, an ESD susceptibility analysis, and an FMECA on their patient monitoring system. Total value was $4,500.

A project was completed for Westinghouse. The task called for data contained in the RAC databases to be reformatted on tape and delivered in support of an Air Force contract to Westinghouse. Total value was $2,700.

An ESD analysis of selected parts for Beech Aircraft was completed and delivered. Total value was $2,200.

3.2 New Products Produced

Four new products were released for distribution during FY'88. They were as follows:

Microcircuit Screening Analysis - MDR-22

This 169 page publication makes fallout rate data on integrated circuits available to RAC users. This data can be used as a baseline to define typical fallout rate values as a function of device and screen stress variables.

Microcircuit Screen Data - MDR-22A

This publication contains 375 pages of detailed microcircuit screening data used to develop the analyses of MDR-22, "Microcircuit Screening Analysis."

Discrete Semiconductor Device Reliability - DSR-4

DSR-4 contains detailed field and test reliability data on a wide range of discrete semiconductor devices, liquid crystal displays, and photovoltaic cells. The data is organized to facilitate location of necessary information in a minimum of time.

A Primer for DoD Reliability, Maintainability and Safety Standards - PRIM-1

This publication contains descriptive synopses of the 38 most often used military standards, specifications and handbooks dealing with reliability, maintainability and safety currently available. It provides a concise and pertinent overview of the most important military documents currently in the field.

	FY'88
Databooks (1 per year required)	MDR-22 MDR-22A DSR-4
State of the Art Reports (2 per year required	PRIM-1
Critical Review & Technology Assessments (1 per year required)	None

FIGURE 3-1: PUBLICATIONS MATRIX

3.3 Product Sales

Figure 3-2 shows RAC catalog number, product title, and quantity distributed for FY'88:

Catalog No.	Title	Quantity Distributed
DSR-3	Transistor/Diode Data	10
DSR-4	Discrete Semiconductor Device Reliability	193
EEMD-1	Electronic Equipment Maintainability	7
EERD-2	Electronic Equipment Reliability Data	21
FMDR-21A	Diskette Version of MDR-21A	4
FNPRD-3	Diskette Version of NPRD-3	22
MDR-14	Hybrid Circuit Data	10
MDR-15	Digital Microcircuit Data	7
MDR-18	Memory/LSI Data	5
MDR-19	Digital SSI/MSI Data	8
MDR-20	Linear Interface Data	9
MDR-21	IC Trend Analysis Databook	16
MDR-21A	IC Field Experience Databook	18
MDR-22	Microcircuit Screening Analysis	151
MDR-22A	Microcircuit Screening Data	121
MFAT-1	Microelectronics Failure Analysis Techniques	63
EOS-1	1979 EOS/ESD Proceedings	154
EOS-2	1980 EOS/ESD Proceedings	922
EOS-3	1981 EOS/ESD Proceedings	134
EOS-4	1982 EOS/ESD Proceedings	89
EOS-5	1983 EOS/ESD Proceedings	99
EOS-6	1984 EOS/ESD Proceedings	273
EOS-7	1985 EOS/ESD Proceedings	204
EOS-8	1986 EOS/ESD Proceedings	436
EOS-9	1987 EOS/ESD Proceedings	84
NONOP-1	Nonoperating Reliability Data	207
NPRD-3	Nonelectronic Parts Reliability Data	235
NPS-1	Analysis Techniques for Mechanical Reliability	45
PRIM-1	A Primer for DoD Reliability Maintainability & Safety Standards	117
RAC-NRPS	Nonoperating Reliability Prediction Software	14
RDH-376	Reliability Design Handbook	139
SOAR-2	Practical Statistical Analysis for the Reliability Engineer	47
SOAR-3	IC Quality Grades: Impact on System Reliability and Life Cycle Costs	47
SOAR-4	Confidence Bounds for System Reliability	26
SOAR-5	Surface Mount Technology: A Reliability Review	252
SOAR-6	ESD Control in the Manufacturing Environment	91
TRS-1	Microcircuit Screening Effectiveness	8
TRS-2	Search & Retrieval to IRPS Proceedings: 1968-1978	3
TRS-2A	Search & Retrieval to IRPS Proceedings: 1979-1984	4
TRS-3A	EOS-ESD Technology Abstracts	1
TRS-4	Search & Retrieval Index to EOS/ESD Proceedings: 1979-1984	4
TRS-5	Search & Retrieval Index to ISTFA Proceedings: 1978-1985	7
VZAP-1	Electrostatic Discharge Susceptibility Data	24
	TOTAL	4,331

FIGURE 3-2: RAC DOCUMENT DISTRIBUTION FY'88

3.4 Publications Reprinted

Additional quantities of the following RAC publications were reprinted to meet order demands:

Publication	Title	No. Reprinted
SOAR-2	Practical Statistical Analysis for the Reliability Engineer	200
NPRD-3	Nonelectronic Parts Reliability Data	300
SOAR-5	Surface Mount Technology: A Reliability Review	450
RDH-376	Reliability Design Handbook	300

3.5 Meetings/Conferences Attended

A total of 106 meetings and conferences were attended by personnel from the Reliability Analysis Center. Most of the these meetings were in support of special studies projects. Other meetings/conferences attended included:

J. Carey, D. Tyler, and R. A. Crisafulli visited Sacramento, CA on 7-11 December to do a series of RAC capabilities presentations.

W. Crowell traveled to several organizations in the Cleveland area during January of 1988 to collect reliability data on various parts types for the RAC databases.

S. Flint met with Dr. Marvin Roush, Chairman of University of Maryland's Reliability Engineering Department , on 21 April 1988 to discuss RAC services.

J. Carey and W. Denson traveled to Raytheon in Andover, MA on 25-27 April to collect data for the RAC.

B. Denson met with Gerard Collas of Bull (in France) during May of 1989 at the IIT Research Institute Beeches Technical Campus to discuss RAC data.

S. Flint and W. Denson met with two Korean visitors (guests of RADC) during June of 1988 to discuss RAC services.

S. Flint and C. Carroll traveled to Picatinny Arsenal in Dover, NJ to do a RAC capabilities presentation the last week of June 1988.

N. Fuqua and S. Kus traveled to Warner Robins Air Logistics Command to conduct a Reliability and Maintainability Training Seminar on 21-23 June at Robins AFB, GA

S. Flint attended the annual DLA IAC Manager's Meeting at Johns Hopkins University in Baltimore, MD on 14 and 15 July, 1988.

J. Carey and D. Tyler gave a RAC capabilities briefing at the Ogden Air Logistics Center at Hill AFB, OK on 17 July 1988.

J. Carey and D. Tyler gave a RAC capabilities briefing at the San Antonio Air Logistics Center at Kelly AFB, TX on 21 July 1988.

W. Crowell, N. Pfrimmer, and K. Lindquist attended the EOS/ESD Symposium in Anaheim, CA on 26-30 September 1988.

3.6 Training Courses

During FY'88 a total of eleven (11) Design Reliability Training Courses (DRTC), three (3) Statistical Process Control (SPC) Training Courses, and six (6) Testability Practices Today (TPT) Training Courses were presented. The following is a list of locations, dates, attendance and type of course presented.

Course	Location	Dates	Attendance	Type
DRTC	Nilsen Industries Ltd Victoria, Australia	10/12-10/15/87	24	On-site
TPT	Quality Inn Syracuse, NY	10/13-10/15/87	17	Open
DRTC	Nilsen Industries Ltd Melbourne, Australia	10/19-10/22/87	20	On-site

DRTC	Avibras Aerospace Indust.. S. J. Campos SP, Brazil	11/16-11/19/87	39	On-site
TPT	Town & Country Hotel San Diego, CA	11/17-11/19/87	12	Open
DRTC	Marriott Hotel Orlando, FL	12/7-12/10/87	58	Open
SPC	Marriott Hotel Orlando, FL	12/7-12/10/88	8	Open
DRTC	Naval Avionics Center * Indianapolis, IN	1/11-1/14/88	60	On-site
DRTC	Varian Associates Palo Alto, CA	2/1-2/4/88	28	On-site
DRTC	Swedish Space Corp. Stockholm, Sweden	2/11-2/25/88	21	On-site
DRTC	Town & Country Hotel San Diego, CA	3/14-3/17/88	47	Open
SPC	Town & Country Hotel San Diego, CA	3/14-3/17/88	10	Open
TPT	Holiday Inn Orlando, FL	3/29-3/31/88	16	Open
TPT	Govt. of India New Delhi, India	4/13-4/15/88	30	On-site
TPT	Govt. of India Bangalore, India	4/18-4/20/88	30	On-site
DRTC	Naval Avionics Center Indianapolis, IN	5/2-5/5/88	35	On-site
SPC	Omni Virginia Beach Hotel Virginia Beach, VA	6/6-6/9/88	14	Open
DRTC	Omni Virginia Beach Hotel Virginia Beach, VA	6/6-6/9/88	40	Open
TPT	Virginia Beach Plaza Hotel Virginia Beach, VA	7/12-7/14/88	17	Open
DRTC	Naval Air Engineering Ctr. * Lakehurst, NJ	8/22-8/25/88	30	On-site

* Revenue reflected as special study; not user receipts

4.0 BASIC RAC DEVELOPMENT EFFORTS

During the past year the Management Information System (MIS) at the RAC has grown from a small check processing system to an integrated and self-supporting information system. RAC contacts, including those from product sales, training course attendance, data sources, symposium contacts, surveys, magazine responses, and those requesting information have been consolidated into one centralized contact file. From this contact file, the RAC is now able to better target those individuals and companies which require reliability information and help determine the needs of the overall reliability community. Integrated with contact information was the capability to automatically track and report on product sales/inventory, training course attendance, service requests, advertising effectiveness, sales trends, and customer/contact growth.

A computerized history of RAC training courses was also completed, along with new capabilities for monthly reporting, and automation of the databook inventory.

The RAC has instituted off-site storage of backup tapes, course slides, and other essential materials.

With the RAC relocation, the RAC Library was completely revamped. All out-of-date documents were weeded out, the physical layout was changed, and the backlog of library documents waiting for input was eliminated. The library is now completely automated and contains an abstract for each document.

Data acquisition personnel visited approximately 50 different companies and government agencies in an effort to promote the RAC and collect data.

Work has continued on development of RAC databases. With the advent of the new databook entitled, "Electrostatic Discharge Susceptibility Data" (VZAP-2) the VZAP database has more than doubled in size.

Current status of the various RAC databases is shown in Figure 4-1:

Database	Software Status	Data Status	Future Direction
IC	Active	Backlog - 6900 records	Continue and add VZAP damage threshold
VZAP	Active	Current	Continue, merge with IC & Discrete
Non-Electronic	Updating File Structure	No Backlog	Expand Scope and Data Collection
Discrete	Updating File Structure	No Backlog	Expanding Opto Section & add VZAP threshold data and data collection
Library	Active	No Backlog	Continue
Hybrid	N/A	N/A	Unknown
Parts Breakdown	Active	No Backlog	Continue
System RAM	Active	No Backlog	Data collection

FIGURE 4-1: RAC DATABASE STATUS

Much work was completed in the area of developing/upgrading promotional materials. The revamp of the RAC Newsletter continued with favorable responses. The RAC Products and Services Catalog was automated on the RAC desktop publishing system for ease of changes. Based on recommendations and advice from a consultant, a new capabilities brochure was developed and will be available for distribution in FY'89.

Three new handbooks/databooks and one new state of the art report were released for distribution during FY'88. Work began on two handbooks/databooks and three state of the art reports.

5.0 SPECIAL STUDIES

5.1 Current Projects

All new special studies started during the current contract are listed below, including name, sponsor, IITRI project number, RADC project number, applicable SOW paragraph, level of funding for FY'88 and a brief description.

SPC For Selected Pilot Production Areas - Naval Avionics Center, IITRI Project A06239 - R-003, SOW Para 4.1.4.4. Level of Funding - $157,402

The objective of this project is to provide success in at least six pilot areas by employing SPC and provide an implementation plan that this Center will use in employing SPC throughout the Center. The desired goal of this program is to improve productivity by increasing quality as well as to provide objective techniques based on data to continuously improve all points within a process by identifying and reducing sources of variability.

Reliability Support for EP/TAB Devices - U. S. Army, ARDEC, IITRI Project A06240 - R-001, SOW Paras 4.1.4.2, 4.1.4.7. Level of Funding - $52,225

The Reliability Analysis Center is supporting the RAM assessment of a Tape Automated Bonding (TAB) process utilized to manufacture hybrid integrated circuits. This technology is being considered for a "smart" munitions application. RAC efforts have included the development of an environmental test program and an industry survey to determine current TAB manufacturers and processes. Interpretation and analysis of this information will assure with some confidence that a reliable product/technology is being designed and accepted for use in smart munitions.

Computerized Shelter Database - Phase I - U. S. Army Natick Research and Development Engineering Center, IITRI Project A06241 - R-002, SOW Para 4.1.4.19. Level of Funding - $100,863.

The objective of this effort is to develop a database consisting of maintainability information on the FSC 5411 family of shelters. Emphasis was placed on developing a database to include shelter data from the Air Force, Army, Navy and Marine Corps. Each service's data reporting system is being examined to determine the type and quantity of shelter data being reported.

SPC Assessment and Planning - U. S. Army, Watervliet Arsenal, (WVA) IITRI Project A06243 - R-005, SOW Para 4.1.4.4. Level of funding - $189,936.

The objective of this project is to assess WVA manufacturing and administrative aspects, determine appropriate techniques and develop training program options together with an outline of the long term SPC program.

Technical Support to Letterkenny Army Depot (LEAD) - U. S. Army, ARDEC, IITRI Project A06244 - R-006, SOW Paras 4.1.4.15 and 4.1.4.16. Level of funding - $192,150.

The objective of the overall effort is to integrate quality, reliability, and maintainability functions into the Letterkenny Evaluation, Analysis, and Planning (LEAP) Program. Working with the Letterkenny, Production Based Modernization Agency, and ARDEC personnel, the support includes the following: assistance in development of program scope and plans for the integration of RAM and QA into LEAP program information systems; identification of requisite input and output parameters, process specification, and data storage reliability needed to effect the collection and reporting of accurate and timely process information; definition of system functional requirements as criteria for the design and implementation phases.

Feedback Analysis Network (FAN) - Phase III - U. S. Army AMCCOM, IITRI Project A06246 - R-027, SOW Paras 4.1.4.19 and 4.1.4.7. Level of funding - $297,000.

The objective of this effort is to provide maintenance, user support and system expansion of the system previously developed for Phase II. The Feedback Analysis Network (FAN) has been developed in response to a need to empirically prioritize end item improvement needs. Improvement programs include Product Improvement Programs (PIPs), Material Testing Technology (MTTs), etc. The concept expanded to include lessons learned and cost information.

Production Readiness Enhancement Program (PREP) 1988 - U. S. Army, Munitions Production Base Modernization Agency (MPBMA), IITRI Project A06247 - R-015, SOW Paras 4.1.4.6, 4.1.4.3, 4.1.4.4. Level of funding - $475,000.

The objective of this program is to assist MPBMA in integrating readiness, reliability, availability, maintainability and quality into the U. S. Army Munitions Production Base. The tasks associated with PREP are as follows: definition of RAM requirements at each life cycle stage of

munitions production facilities planning, design, implementation, use, layaway and reactivation; support of engineering project managers in the RAM disciplines; support institutionalization of Quality and Reliability into the PBMA environment.

Total Quality Management - U. S. Naval Supply Center, IITRI Project A06249 - R-009, SOW Para 4.1.4.4. Level of funding - $137,917.

The objective of this program is to implement Phase I (over a one-year period) of a Total Quality Management (TQM) approach to continuous improvement at Naval Supply Center (NSC), to prototype TQM in three pilot areas, and to position NSC for successful implementation of TQM across NSC.

R&M Support for Airport Surface Detection Equipment (ASDE-3) - Federal Aviation Administration (FAA), Surveillance & Weather Sensors Division, IITRI Project A06250 - R-019, SOW Paras 4.1.4.2 and 4.1.4.4. Level of funding - $27,070.

The objective of this effort is to continue providing the FAA with Reliability and Maintainability (R/M) support during acquisition of the airport surface detection equipment systems. These systems, designated ASDE-3, are intended to replace earlier models and are targeted for 25 sites in the initial acquisition R/M engineering support will be provided throughout the procurement cycle on a continuing basis. The support will consist of R/M documentation review and analysis, data collection review and analysis, and liaison and consultation as necessary with both the FAA and United Technologies, Norden Systems Division, the ASDE-3 contractor. The objective of this effort is to give the FAA timely and accurate analyses of the contractor's data items. Without these inputs the FAA will not be in a position to make decisions regarding program direction at the most appropriate times.

Printed Wiring Board Reliability - U. S. Air Force, RADC/RBER, IITRI Project A06253 - R-008, SOW Para 4.1.4.10. Level of funding - $20,000.

The objective of this project is to review and improve printed wiring board reliability techniques and associated standards, primarily through attendance at professional seminars and specification review, preparation, and update.

Mass Spectrometer - U. S. Army AMCCOM, IITRI Project A06254 - R-007, SOW Para 4.1.4.9. Level of Funding - $27,146.

This effort involves performing a reliability analysis on the Mobile Mass Spectrometer MM1 produced by Bruker-Franzen Analytik GmbH, Bremen, West Germany, under procurement by the United States Army. The intent is to assist the U. S. Army and Bruker-Franzen Analytik GmbH with improving the Field Reliability of the MM1 Mobile Mass Spectrometer by suggesting design improvements, based on the results of a Failure Modes Effects & Criticality Analysis (FMECA) to be performed.

Reliability Support of the AN/ALQ-184(V) ECM POD for WR-ALC - U. S. Air Force, IITRI Project A06255 - R-012, SOW Paras 4.1.4.1 and 4.1.4.4. Level of funding - $225,000.

The project objective is to provide R/M expertise in support of the development of the AN/ALQ-184(V) ECM POD. The result will be a more reliable and maintainable ECM POD. Specific objectives include determination of actual R/M growth, specification of environmental facilities for R/M growth and R/M data collection and management.

NAVSEA ESD Control Program - Naval Sea Systems Command, IITRI Project A06257 - R-022, SOW Para 4.1.4.12. Level of funding - $36,158.

The project objective is to provide technical assistance to Naval Sea Systems Command in the establishment and maintenance of an Electrostatic Discharge Control Program.

Reliability Centered Maintenance (RCM) Data Analysis Center - U. S. Marine Corps, IITRI Project A06263 - R-017, SOW Para 4.1.4.14 and 4.1.4.19.6. Level of funding - $284,446.

This project objective is to perform FMEA and RCM Analyses on Marine vehicles and ground support equipment to develop tailored maintenance programs and to develop a reliability/maintainability tracking system.

Fault Isolation and BIT Analysis of the MILSTAR Mission Control Element (MCE) - U. S. Air Force - AFSC/SD, IITRI Project A06264 - R-023, SOW Para 4.1.4.3. Level of funding - $200,000.

The objective of this project is to determine current fault isolation levels, maximum obtainable fault isolation levels and a realistic MTBF for the MILSTAR Mission Control Element (MCE).

Reliability/Maintainability Technology Transition - U. S. Air Force, RADC/RBE, IITRI Project A06265 - R-028, SOW Para 4.1.4, 4.1.10, 4.1.19, and 4.1.6.4. Level of funding - $20,000.

The RAC is supporting RADC efforts to standardize and institutionalize Reliability/Maintainability within the U. S. Air Force. In RADC's role as DoD Lead Standardization Activity for R&M standardization, they engage from time to time in activities which benefit from the RAC's experience in technology transfer, and from the wide audience RAC materials receive.

Quality Productivity for Depot Repair (AGMC) - U. S. Air Force, IITRI Project A06274 - R-029, SOW Paras 4.1.3.6, 4.1.4.4, 4.1.4.15, 4.1.4.14, 2.6.1. Level of funding - $93,521.

To develop Statistical Process Control (SPC) under the Deming management philosophy to maintenance workloads including the displacement gyro system, through training and program guidance in SPC. To introduce new screening procedures to diagnose and prevent poor reliability guidance systems from being introduced to field use following maintenance, using SPC procedures developed for repair/overhaul.

Design Definition For a Micro-Time Stress Measurement Device - U. S. Air Force, RADC/RBET, IITRI Project A06279 - R-031, SOW Paras 4.1.4.1 and 4.1.4.14. Level of funding - $205,675.

To conduct the Design Definition phase for the full scale development of hybrid micro TSMDs which will be suitable for mounting on avionics/electronic circuit boards/modules.

Develop Reliability, Maintainability and Testability (RM&T) Concepts in Electrical and Computer Engineering Curricula (FIT) - U. S. Air Force, RADC/RBET, IITRI Project A06280 R-033, SOW Paras 4.1.3.6 and 4.1.4.4. Level of funding - $14,250.

The object of this effort is to develop standards for, and the content of, RM&T training which can be integrated into an ECE curriculum and apply it in a test application at Florida Institute of Technology.

MIL-STD-471A Update - U. S. Air Force, RADC/RBET, IITRI Project A06281 - R-032, SOW Para 4.1.4.10. Level of funding - $33,250.

The object of this effort is to prepare an updated version of MIL-STD-471.

Field Failure Return Program (FFRP) - U. S. Air Force, RADC/RBRE, IITRI Project A06283 - R-036, SOW Paras 4.1.4.7 and 4.1.4.19. Level of funding - $28,500.

The purpose of the FFRP is to establish and operate a clearinghouse for failure reporting and corrective actions on microcircuits which fail during operation in DOD equipment.

Reliability Support for WR-ALC Vehicle Management Division - U. S. Air Force, IITRI Project A06290 - R-039, SOW Paras 4.1.4.4 and 4.1.4.17. Level of funding - $9,852.

The purpose of this project is to provide R&M engineering support to integrate R&M 2000 objectives into the procurement, operation & maintenance of AF support vehicles.

EOS/ESD Failure Analysis Training - U. S. Air Force, Aerospace Guidance & Metrology Center, IITRI Project A06293 - R-030, SOW Para 4.1.4.12. Level of funding - $16,521.

The purpose of this effort is to assist Newark AFB in the training of their personnel to conduct failure analysis of parts failing from electrostatic discharge (ESD) and electrical overstress (EOS).

Preparation of R&M Guidebook on Motivation Principle - U. S. Air Force, RADC/RBE, IITRI Project A06294 - R-026, SOW Paras 4.1.3.1 and 4.1.4.10. Level of funding - $57,000.

The object of this effort is to prepare a manual explaining the R&M 2000 Motivation Principle and provide guidance and techniques for implementing its precepts.

5.2 Completed Projects

Logistics Readiness (RAM) System - U. S. Army, Army Research and Development Center (ARDC), IITRI Project A06238 - R-004, SOW Para. 4.1.4.19. Level of funding - $317,063.

This project supported the U. S. Army (ARDC) Battlefield and Support Division through the development of a Logistic Readiness (RAM) System capable of achieving a high level of field operational readiness in a cost-effective manner. This system supported the materiel logistic process by establishing and maintaining a current and readily accessible data base of regulations, requirements, specification and RAM characteristics relative to component and materiel items in the Army's inventory. The overall function of the RAM system was to provide a paperless management tool which reduced the administrative time required to issue and monitor a request for materiel.

AMAS Reliability Assessment and Enhancement - U. S. Army AMCCOM, IITRI Project A06252 - R-018, SOW Para 4.1.2.3. Level of funding - $500,000.

The objectives of this proposed study were; to develop a methodology for reliability and availability assessment of combined hardware/software systems, to apply this methodology to the Automated Material System (AMAS), and to modify or enhance the system to realize the full benefits of the reliability analysis.

6.0 FINANCIAL SUMMARY FY'88

Operating expenditures for carrying out the Reliability Analysis Center's on-going operational functions and satisfying individual user inquiry and study requiremnents for the year totalled $ 4,178,753. Funding for FY'88 to date from all sources amounted to $4,863,502. The breakdown in RAC funding is listed below.

Core RAC (DTIC & RADC)	$ 541,495.
Special Studies	3,903,462.
Technical Inquiries	30,252.
Products & Services	145,899.
Training Courses	242,394.
TOTAL	$ 4,863,502.

Funding for Special Studies is further broken down in Figure 6-1.

IITRI PROJ #	RADC PROJ #	PROJECTS/TASKS	INCOME
A06237	N/A	SPECIAL STUDIES ADMIN & MGMT	$ 185,517
A06238	R-004	LOGISTICS READINESS (RAM) SYSTEM	$ 317,063
A06239	R-003	SPC FOR SELECTD PILOT PROD AREAS	$ 157,402
A06240	R-001	REL SUP FOR EP/TAB DEVICES	$ 52,225
A06241	R-002	COMPUTERIZED SHELTER DATABASE	$ 100,863
A06243	R-005	SPC ASSESSMENT AND PLANNING	$ 189,936
A06244	R-006	TECHNICAL SUPPORT LETTERKENNY	$ 192,150
A06246	R-027	FEEDBACK ANALYSIS NETWORK	$ 297,000
A06247	R-015	PREP-88	$ 475,000
A06249	R-009	NAVAL SUPPLY CENTER SPC	$ 137,917
A06250	R-019	R&M SUPPORT (ASED-3)	$ 27,070
A06252	R-018	AMAS REL ASSESS & ENHANCEMENT	$ 500,000
A06253	R-008	PRINTED WIRING BOARD RELIABILITY	$ 20,000
A06254	R-007	MASS SPECTROMETER	$ 27,146
A06255	R-012	AN/ALQ-184 (ROBINS AFB, GA)	$ 225,000
A06257	R-022	NAVSEA ESD CONTROL PROGRAM	$ 36,158
A06263	R-017	REL. CNTRD. MAINT. DATA ANAL CTR	$ 284,446
A06264	R-023	FAULT ISOL. & BIT ANAL - MILSTAR	$ 200,000
A06265	R-028	REL/MAINT TECHNOLOGY TRANSITION	$ 20,000
A06274	R-029	QUAL PROD FOR DEPOT REPAIR AGMC	$ 93,521
A06279	R-031	DSGN DEFINITION FOR A MICRO TSMD	$ 205,675
A06280	R-033	FIT SUPPORT-ECE CURRICULA	$ 14,250
A06281	R-032	MIL-STD-471A UPDATE	$ 33,250
A06283	R-036	EST A DOD FIELD FAILURE RTN PROG	$ 28,500
A06290	R-039	REL SUP WR-ALC VHCLE MGMT DIV	$ 9,852
A06293	R-030	EOS/ESD FAILURE ANALYSIS TRAINING	$ 16,521
A06294	R-026	PREPARATION OF R&M 2000 GUIDEBK	$ 57,000
	GRAND TOTAL PROJECTS		$3,903,462

FIGURE 6-1: SPECIAL STUDIES FUNDING FOR FY'88

7.0 INFORMATION FROM IAC USERS

The RAC instituted a customer survey/feedback function in which a RAC customer service representative contacted a specific segment of customers who had purchased a particular product, i.e., handbook/databook, state-of-the-art report, etc. The information gained from these surveys will be used to further enhance the development of future RAC products.

A Project Close Out Form was implemented to solicit customer comments on the technical quality, performance schedule, return on resources provided, and additional comments as required on all RAC Special Studies. Comments received on the forms during FY'88 were favorable.

The RAC has instituted an agreement with Information Handling Services to distribute copies of all RAC handbooks/databooks and state-of-the-art reports on microfiche.

7.1 User Feedback on IAC Services

A total of 4,331 books and services were ordered in FY'88. In addition, 26 special studies were undertaken for Government customers and 20 training courses were presented to an audience of 556 students.

Additionally, examples of two user letters received during this reporting period are included in Appendix C.

7.2 User Surveys

A telephone survey was conducted among customers who purchased the RAC document entitled, "Nonoperating Reliability Data", NONOP-1. A sampling of 17.2 % of those who purchased NONOP-1 were selected to be contacted. Of the sampling selected, 65% were contacted directly and were asked the following questions":

- Did they receive the book promptly?
- Was the book what was expected?
- Did the book address the required needs?
- How could the book be improved?
- What other databooks would be helpful in their job?

- In their job, what kind of information was hardest to find?
- Did they have any general comments concerning the RAC or its products & services?

Ninety-five percent of those customers who were polled received their order in a timely manner. Sixty-five percent were pleased with the contents of the product. Feedback was received on suggested improvements to NONOP-1, other types of databooks which would be useful, and general comments concerning the RAC and its products and services. Generally, the comments were favorable and provided useful feedback for improving future products.

A customer survey on the effectiveness of the RAC Newsletter was conducted for RAC by the firm of Scott, Brown & Co. Results of this survey are as follows:

- Total readership of the RAC newsletter is more than 28,000.
- At least half of the publication is read by 86% of the respondents.
- The RAC newsletter is providing important source information for R&M personnel.
- 91% of the respondents read the publication at work.
- The publication more than holds its own against competing technical materials distributed at the work site.
- An overwhelming majority of the respondents reported the articles were well-written, informative, and told them what they wanted to know.
- 97% of the respondents reported the data was clear and concise.
- 75% of the respondents spend more than 15 minutes reading the publication.

The firm also concluded that the RAC newsletter is widely read by its audience of technical and engineering professionals mainly in R&M. It meets the reader's criteria for a sound, well-edited technical publication. The data is clear, the writing concise, and the data sound. The survey provided clues to increased readership and reader acceptance.

Scott, Brown, & Co. recommends that with a high "pass-on" readership, the reach of the publication should be broadened. Numerous suggestions and requests for more technical data and more frequent publication of the newsletter, together with its extraordinary high readership, reaffirms the fact that the RAC Newsletter is attuned to the needs of, and meets the criteria of, the R&M industry.

8.0 RAC PROFESSIONAL STAFF

The following technical professional staff memebers were assigned to the Reliability Analysis Center opeations during FY'88. Personnel supporting RAC less than 50% of the time are not included on this list. Titles and specialty areas are included.

S. Flint, Manager of Research
Director

R. Arno, Associate Engineer
Nonelectronic Parts Reliability

E. Bolden, Research Engineer
Systems Reliability

J. Carey, Research Assistant
Data Acquisition

C. Carroll, Research Programmer Analyst
Systems Integration, Value Engineering

G. Chandler, Research Assistant
Reliability Data

D. Coit, Manager of Research
Nonelectronic/Nonoperating System Reliability

C. Cox, Associate Data Analyst
User Awareness

D. Crossland, Administrative Supervisor
Office Management

W. Crowell, Research Assistant
Data Acquisition

W. Denson, Research Engineer
Electrostatic Discharge, VLSI Reliability

K. Dey, Science Advisor
Statistics, Quality Productivity Improvement

W. Doremus, Senior Engineer
Production Readiness

D. Dylis, Research Engineer
Nonelectronic Parts Reliability, Systems

K. Free, Associate Programmer Analyst
Systems Analysis

N. Fuqua, Senior Engineer
Component and Systems Reliability, Training Course Instructor

M. Hartz, Science Advisor
Statistics, Mathematical Modeling

K. Henniger, Assistant Programmer Analyst
Systems Analysis

J. Hill, Associate Engineer
Microcircuit Reliability

K. Huss, Research Engineer
Systems Reliability

J. Irving, Research Programmer Analyst
Systems Analysis

S. Kus, Research Engineer
Systems Reliability, Training Course Instructor

K. Lindquist, Division Administrative Assistant
Administrative Support, Systems Analysis

D. Mahar, Associate Engineer
Microcircuit Reliability

N. Pfrimmer, Division Administrative Assistant
Training Courses and Workshops, Marketing and User Awareness

M. Priore, Associate Engineer
Microcircuit Reliability

B. Radigan, Research Assistant
Systems Analysis

D. Rash, Associate Engineer
Microcircuit Reliability

J. Reed, Associate Data Analyst
Systems Analysis

R. Sadlon, Associate Engineer
Mechanical Reliability

J. Saporito, Associate Engineer
Systems Reliability, Testability

D. Tyler, Associate Engineer
FMEA, FMECA, Systems Reliability

R. Wanner, Associate Programmer Analyst
RACIS Coordinator, Depot Readiness

R. Wawrzusin, Research Engineer
CAD/CAM/CIM, Depot Readiness

S. Wheat, Assistant Programmer Analyst
Systems Analysis

J. Wilbur, Research Engineer
RAC Training Courses

APPENDIX A

PRODUCTS & SERVICES CATALOG

1988 PRODUCT AND SERVICE CATALOG

RAC

Reliability Analysis Center

P.O. Box 4700 • Rome, NY 13440-8200 • (315) 330-4151 • AV 587-4151

The Reliability Analysis Center is a DoD Information Analysis Center operated by IIT Research Institute, Rome, New York

The information and data contained herein have been compiled from government and nongovernment technical reports and from material supplied by various manufacturers and are intended to be used for reference purposes. Neither the United States Government nor IIT Research Institute warrant the accuracy of this information and data. The user is further cautioned that the data contained herein may not be used in lieu of other contractually cited references and specifications.

Publication of this information is not an expression of the opinion of The United States Government or of IIT Research Institute as to the quality or durability of any product mentioned herein and any use for advertising or promotional purposes of this information in conjunction with the name of The United States Government or IIT Research Institute without written permission is expressly prohibited.

RAC RELIABILITY ANALYSIS CENTER

P O Box 4700, Rome, NY 13440-8200 • 315/330-4151

The Reliability Analysis Center (RAC) develops and offers for sale State-of-the-Art Reports, Data Analysis Books and conducts Special Studies on a continuing basis. These products and services are designed to provide the reliability and quality control communities with up-to-date information on relevant topics. A variety of topics, including electronic and non-electronic device reliability, electro-static discharge susceptibility, equipment and system reliability, maintainability and system level analysis are included within the scope of the RAC.

The RAC has been called upon by various Offices of the Department of Defense as well as defense contractors to provide information or independent third-party assessments of designs during the procurement process. Because the RAC does not stand to benefit from either a favorable or unfavorable appraisal of any contractor's design, an unbiased analysis can result.

The prices charged for RAC products and services are lower than might be expected for information as valuable. The information contained in products such as the State-of-the-Art Reports can replace many hours of research, and Special Studies such as Failure Modes and Effects Analysis (FMEAs) or Parts Stress Predictions (MIL-HDBK-217 Prediction), the cost to the customer can be well below that of conducting the same study in-house.

FULL SERVICE PARTICIPATION PLAN

The Reliability Analysis Center offers a Full Service Participation Plan which affords rapid access at all times to the vast RAC reliability resources by opening a Participating Membership account. The plan is open to all U.S. Government agencies, government contractors, commercial producers and users, device vendors, laboratories, educational institutions and qualified foreign organizations.

Products and Services available under this plan include:

- Reliability and Maintainability Engineering
- Statistical Consulting
- Bibliographical/Literature Searches
- EOS/ESD Consulting
- RAC Publications
- Customized Data Searches

Participants automatically receive:

- Access to RAC Resources - without the delay and expense of issuing individual purchase requests (limited only by the balance in user's RAC account)
- Reliability Publications - one copy of each publication as they are issued at 20% off list
- Discount Privileges - additional copies of any RAC publications (except video tapes) at 20% off list
- Account Maintenance - RAC will maintain the account record of funds expended and furnish an account statement every month or at the customer's request

A RAC Full Service Participation Plan can be opened in two ways:

- Pre-deposit of a minimum amount of $500 U.S., $575 Non-U.S.
- A purchase order (not less than $500 U.S., $575 Non-U.S.) with a "not-to-exceed" amount indicated (RAC will bill as needed)
- Checks or purchase orders must show vendor as *IITRI/RAC*

A subscription can be cancelled by RAC if the account balance remains $35.00 or less three consecutive months, or at the customer's request.

Address your correspondence to: Gina Nash, Reliability Analysis Center, P.O. Box 4700, Rome, NY 13440-8200 • Telephone: (315) 337-0900 or Autovon 587-4151.

RELIABILITY PUBLICATIONS

DISCRETE SEMICONDUCTOR DEVICE RELIABILITY DSR-4

Discrete Semiconductor Device Reliability, (DSR-4), is the most comprehensive collection of discrete semiconductor device reliability data and information available since its predecessor DSR-3 was published in 1979.

Compiled from both military and commercial data sources, data is presented on all transistors, diodes and optoelectronic part types currently covered in MIL-HDBK-217E as well as special or low-population parts including:

- GaAs Power FETs
- Transient Suppressor Diodes
- Infrared LEDs
- Diode Array Displays
- Current Regulator Diodes
- Photovoltaic Cells
- Liquid Crystal Displays
- Microwave Diodes
- Microwave Transistors

Pertinent device and application-specific details characterizing the device failure are presented in the detailed data section including:

- Device Type
- Package Type
- Screen Level
- Application Environment
- Temperature
- Electrical Stress
- Number Tested
- Number Failed
- Part Hours

DSR-4 answers questions of concern to reliability engineers including:

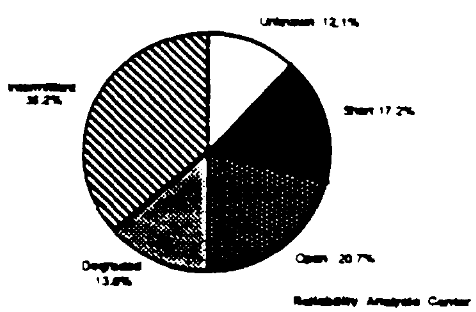
- How have typical device failure rates changed over the last 10-15 years?
- What is a typical diode failure rate?
- Does the exponential failure distribution sufficiently describe discrete semiconductor device failure patterns?
- How do the failure rates of two different transistor types compare?

DSR-4 supplements the information available in publications such as MIL-HDBK-217E, **Reliability Prediction of Electronic Equipment** and MIL-STD-701, **Lists of Standard Semiconductor Devices.** DSR-4 highlights failure rate data on discrete semiconductor device types covered in MIL-HDBK-217E, as well as state-of-the-art devices not in 217E.

This data is critical to design trade-off analyses, reliability growth monitoring and life cycle cost/warranty period analyses.

In addition, failure mode and mechanism data critical to analyses such as Failure Modes, Effects, and Criticality Analyses (FMECAs) is presented in both tabular and graphical formats.

DIODE FAILURE MODE DISTRIBUTION



The DSR-4 data compiled over the last nine years updates the pre-1978 DSR-3 data. The impact of changes in technology and production processes on device reliability is investigated in a joint DSR-3/DSR-4 data analysis, which demonstrates a marked improvement in the failure rates of diodes, transistors, thyristors and LEDs since 1978, especially in the non-MIL devices used in commercial equipment.

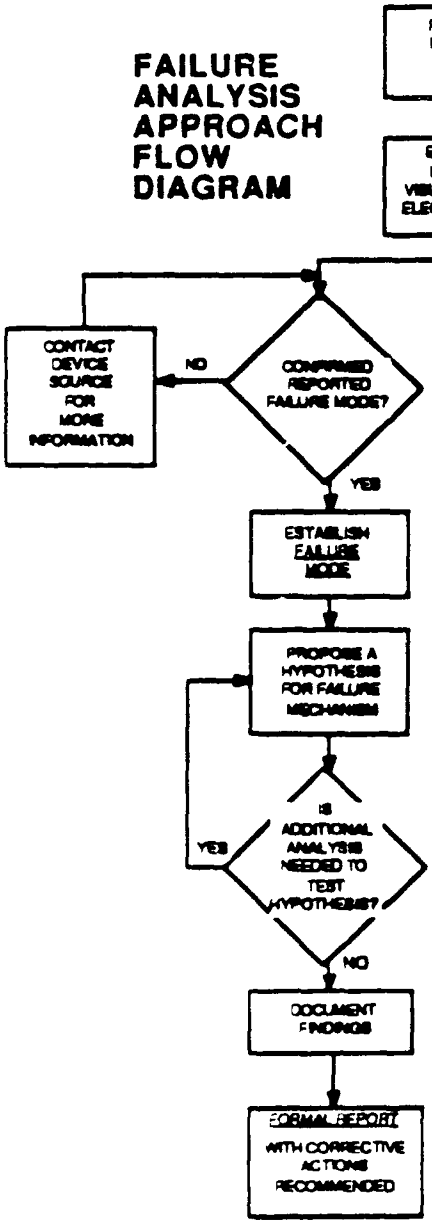
DSR-4 is available for $100 (U.S.) **$120 (Non-U.S.).**

MICROELECTRONIC FAILURE ANALYSIS TECHNIQUES MFAT-1

Destructive Failure Analysis of defective electronic parts is often the key to the solution of reliability problems. But how do manufacturers go about establishing this capability within their own facility?

To address this vital question the Reliability Analysis Center has published **Microelectronic Failure Analysis Techniques, MFAT-1.** This highly instructive document is the result of a joint effort by: a) the Rome Air Development Center, b) General Electric's Syracuse Electornics Laboratory and c) the Reliability Analysis Center. This publication provides detailed steps for the establishment and operation of a cost-effective failure analysis laboratory.

FAILURE ANALYSIS APPROACH FLOW DIAGRAM



This guide was the product of an on-site failure analysis laboratory survey, a document review board composed of acknowledged experts from both government and industry, technical inputs from numerous reliability specialists and extensive literature search.

TABLE OF CONTENTS

MFAT-1 is a procedural guide intended to serve as a tool for the beginning failure analyst as well as a convenient reference source for the experienced analyst and others such as quality and reliability project engineers in the semiconductor industry. It represents a collection of the most useful failure analysis techniques being used by industry leaders in this growing field.

The specific techniques described in detail in this publication include: Fault Isolation, Radiography, Package Ambient Gas Analysis, Infrared Thermal Mapping, Liquid Crystal Analysis, Surface Topography Measurement, Optical Analysis, Metallurgical Analysis, Scanning Acoustical Microscopy, Microbeam Analysis, etc.

MFAT-1 is available for $125 (U.S.) $135 (Non-U.S.).

A PRIMER FOR RELIABILITY, MAINTAINABILITY AND SAFETY STANDARDS PRIM-1

Given the vast array of Military Specifications, Standards and Handbooks available today, it is often very difficult to determine those that most adequately address the Reliability, Maintainability and Safety requirements of a given program without spending a great deal of time and effort to obtain and to study numerous documents.

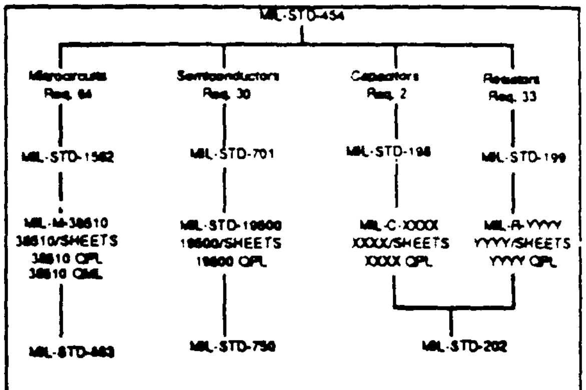
To simplify this arduous task the Reliability Analysis Center has just published **A Primer for Reliability, Maintainability and Safety Standards, (PRIM-1).**

The document contains brief descriptions of the many Military Standards, Specifications and Handbooks dealing with Reliability, Maintainability and Safety currently available. It provides a quick, concise and pertinent overview of the most important military documents in the field.

MAJOR SECTIONS

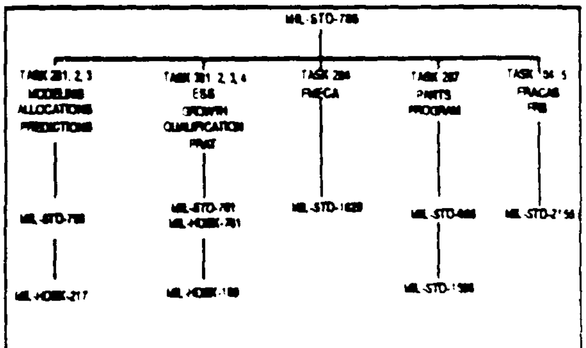
1. **Reliability Program Specifications**
2. **Reliability Assessment Specifications**
3. **Reliability Design Specifications**
4. **Major Parts Specifications**
5. **Maintainability Program Specifications**
6. **Maintainability Design Specifications**
7. **Maintainability Assessment Specifications**
8. **Safety-Related Specifications**

This 400-page publication consists of thirty-eight chapters. Each one deals with a single standard, specification or handbook. It gives a brief description of the document, explains its significance to the program and/or phase of the program, describes the purpose of the document, lists any applicable data item descriptions (DID's) and gives a brief explanation of how to use the document. It explains, where necessary, how to tailor the document's requirements and also identifies those documents which may be unique to a specific branch of the military. An introductory chapter discusses general background issues and guides the reader to the most appropriate section based upon the nature of the inquiry.



RELIABILITY PART/DESIGN-APPLICATION SPECIFICATIONS

Thus the user, provided with a single reference guide to the applicability and use of the most relevant R, M & S military documents, can avoid having to order and review each document separately to determine its application to a specific program, and how to use it. This is especially helpful to proposal efforts by relatively new companies in the field, or companies who may not be familiar with government procurement programs.



RELIABILITY PROGRAM SPECIFICATIONS

PRIM-1 is available for $95 (U.S.) $115 (Non-U.S.).

ELECTROSTATIC DISCHARGE SUSCEPTIBILITY OF ELECTRONIC DEVICES VZAP-1

Electrostatic discharge (ESD) problems are very prevalent today in the electronics industry. ESD control measures can be very expensive and, if not effectively implemented, can result in unnecessary expense. One very necessary element in the effective implementation of an ESD control program is the identification of the ESD susceptibility of the parts being handled or assembled. The identification of these parts is the intent of the 341 page VZAP-1.

Military specifications are also mandating ESD control procedures based on the data contained in the Reliability Analysis Center's VZAP database, from which VZAP-1 was generated. Data contained in VZAP-1 can be used to:

- identify the ESD susceptibility of an equipment
- identify areas where additional transient protection is necessary
- assist in the selection of less susceptible components

VZAP-1 contains detailed susceptibility data (part type, manufacturer, test type, threshold level, failure criteria, etc.) on approximately 700 microcircuits and 500 discrete semiconductor devices. ESD classification data is also presented for these parts (based on the DoD-STD-1686 and DOD-HDBK-263 classification scheme) ordered by generic numbers as well as MIL-M-38510 and MIL-S-19500 numbers.

A brief outline of VZAP-1 is as follows:

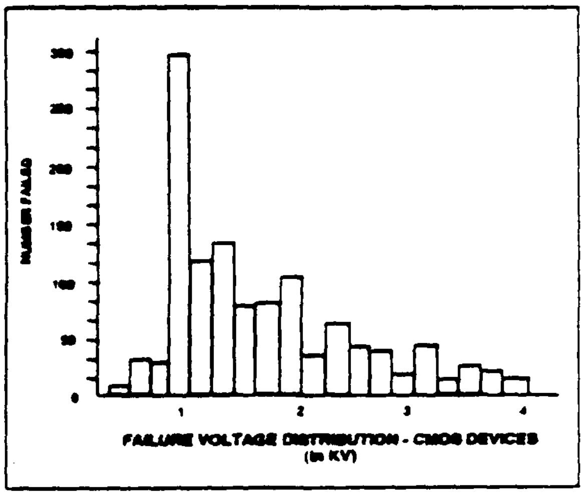
Background Information
- *Test methods*
- *Failure mechanisms*

Detailed Device Susceptibility Data
- Microcircuits
- Discrete Components

Classification Data (per MIL-STD-1686)
- Microcircuits in generic part number order
- Microcircuits in military part number order
- Discrete components in generic part number order
- Discrete components in military part number order

Discussion of sources supplying data to VZAP-1.

In addition to detailed ESD susceptibility on specific parts, data summaries are presented displaying failure voltage distributions for several microcircuit technologies. The following figure is an example of this analysis:



Another RAC product, **SOAR-6, "ESD Control in the Manufacturing Environment,"** when used in conjunction with VZAP-1, recommends ESD control measures based on the susceptibility levels identified by VZAP-1.

VZAP-1 is available for $95 (U.S.) **$105 (Non-U.S.).**

NONOPERATING RELIABILITY PREDICTION SYSTEM RAC-NRPS

Equipments exposed to long periods of storage will experience measurable degradation. When a system is stored for long periods, with short operating times, the majority of failures will occur during nonoperating periods, regardless of the fact that the operating failure rate may appear to be much higher.

To address this important issue, the Reliability Analysis Center introduces the **NONOPERATING RELIABILITY PREDICTION SYSTEM (RAC-NRPS)**, a comprehensive software package designed to predict the impact of nonoperating periods on equipment reliability.

The **RAC-NRPS** analyses are intended to complement predictions of operating reliability. When used in conjunction with an operational failure rate prediction (MIL-STD-217), the combined operational and nonoperational failure rate of a system can give a total and more realistic assessment of reliability.

The **RAC-NRPS** contains facilities to enter and edit assembly and part level data records. All data input routines are designed for speed, while the editing functions allow free movement and editing of all records. Assemblies without parts lists may be included by assigning a failure rate to the assembly during data input. In addition to the part types described in RADC-TR-85-91A, the "Miscellaneous Parts" section allows unique parts to be included in the prediction by assigning a known failure rate.

PERIODIC TESTING MODEL

A specialized model to analyze the effects of *periodic testing* on stored system reliability is also given. The analysis can be performed on an entire system or a single assembly. The test effectiveness, i.e. the proportion of failures detected, may be varied. The reliability model for the exponential distribution is also displayed for comparison with the specialized periodic testing model.

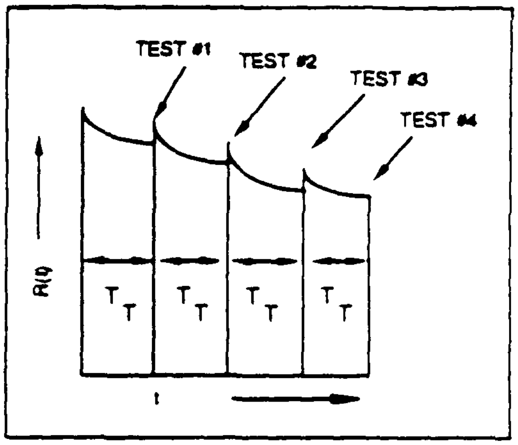
Given a periodic testing schedule to identify failures and restore failed equipment to operational status, the reliability after the N^{th} test interval is given by:

$$R_{(N,t)} = e^{-[N(1-\alpha)\lambda T_T]}\, e^{-\lambda[t-NT_T]}$$

where

$R_{(N,t)}$	=	reliability following test N at time t
N	=	test number
t	=	total storage time
T_T	=	test interval
α	=	test effectiveness (percentage of failures detected by test sequence)
λ	=	system nonoperating failure rate

This relationship is depicted graphically in figure below.



Effects of Periodic Testing on Reliability

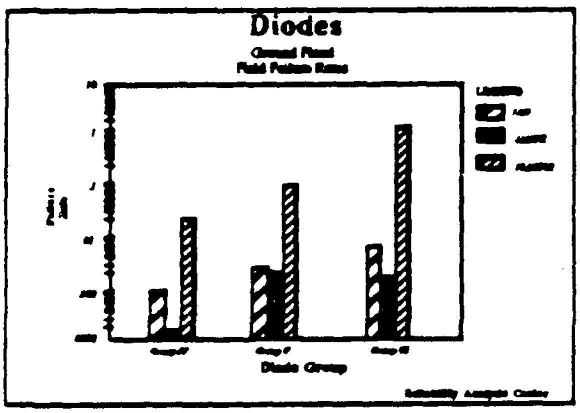
To run, the **RAC-NRPS** requires an IBM PC/XT/AT or 100% compatible computer with a minimum of two diskette drives (a fixed disk is recommended), MS-DOS 2.1 or higher or PC-DOS 2.0 or higher, and a minimum of 384K bytes of RAM. Included with RAC-NRPS is a copy of NONOP-1, "Nonoperating Reliability Databook," a RAC Publication dealing with nonoperating field data.

RAC-NRPS is available for $1,400 (U.S.) $1,450 (Non-U.S.).

NONOPERATING RELIABILITY DATABOOK NONOP-1

Reliability experts agree that equipments exposed to long periods of storage experience measurable degradation. However, until now there has been little agreement on the methods to be used when predicting such degradation. Many of these experts have been using 10 percent of the operational failure rate as an approximation for the nonoperational failure rate; however, the use of "correction" factors is a very approximate method at best. It is intuitively wrong to assume that operating and nonoperating failure rates are directly proportional. Many application and design variables have a pronounced effect on the operating failure rate, yet a negligible effect on the nonoperating failure rate. For example, derating results in a significant decrease in operating failure rate, but can have no effect when no power is applied.

For this reason, the Reliability Analysis Center has put together the **Nonoperating Reliability Databook, NONOP-1.** NONOP-1 contains 328 pages of nonoperating field and test data on an assortment of electrical, mechanical and electromechanical parts. It is the first RAC databook devoted entirely to the reliability of equipments in the nonoperating state. The data presented has been collected by RAC from dozens of government and non-government sources.



Each item, whether a system, sub-system, assembly or component, experiences the effects of environmental stresses. These stresses include temperature cycling, humidity, vibration due to transportation and handling, databook quantifies the effects of these environmental stresses on nonoperating reliability, and discusses many of the failure mechanisms which can occur as a result. Also included is a discussion on the effects of periodic testing on system reliability.

With the data presented in this publication, it is possible to derive accurate nonoperating component failure rates which, when used in conjunction with the **RAC Nonoperating Reliability Prediction System (RAC-NRPS) or RADC-TR-85-91**, will estimate nonoperating system reliability. The system reliability information may be used to perform design trade-offs, to establish testing intervals, to determine when to scrap old supplies or to help compute cost-effective warranty periods. These are important considerations for spare parts inventory or for systems (e.g., missiles) which may spend many years in storage.

SOME OF THE MANY PART TYPES INCLUDED IN NONOP-1

Resistors	Capacitors
Inductors	Diodes
Transistors	Microcircuits
Tubes	Hybrids
Switches	Relays
Connectors	Meters
Pumps	Batteries

NONOP-1 provides summaries and detailed data on a variety of devices. Similar part types are grouped to allow quick comparisons among themselves. Summary data tables provide nonoperating field failure rates, which are compared to predicted failure rate values. (Predicted failure rates have been derived using RAC's Nonoperating Reliability Prediction System (RAC-NRPS), based on the RADC Technical Report, "Impact of Nonoperating Periods on Equipment Reliability;" RADC-TR-85-91). NONOP-1 is intended to complement documents such as RADC-TR-85-91 and MIL-HDBK-217.

NONOP-1 is available for $150 (U.S.) $160 (Non-U.S.).

MICROCIRCUIT SCREENING ANALYSIS MDR-22

This 169 page publication makes fallout rate data on integrated circuits available to RAC users. This data can be used as a baseline to define typical fallout rate values as a function of device and screen stress variables. This publication covers digital, linear, interface, and memory devices.

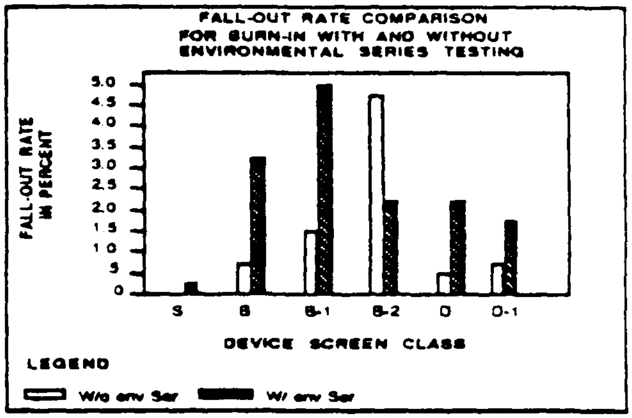
All data used in the development of this publication (which was collected from a variety of external sources) was extracted from the RAC Integrated Circuit Reliability Database.

Various standard screens are analyzed, as well as screening sequences, making this data extremely useful for those who wish to:

1. Compare fallout rates from a particular process or line to industry averages
2. Customize screening tests to optimize the cost/benefit ratio (non-military applications)

Summaries and analysis are presented for various part types (*function, technology, and* package type), "standard screening tests" (environmental and burn-in), temperature, test length and screening sequences. Additionally, to simultaneously quantify the effect of each of these variables, multiple regression analysis models are presented which allow the user to identify a typical industry-wide fallout rate as a function of these variables.

The following example of a typical analysis presented in this publication indicates the fallout rate of devices subjected to rescreening.



Rescreen Fall-Out Rates vs. Screen Class

The cost to the customer of these screening tests varies considerably from test to test and from manufacturer to manufacturer. Careful selection of screening stresses, durations and failure criteria can result in very cost-effective programs that give excellent quality assurance. The data in this publication is designed to allow the user to intelligently make such selections.

MDR-22 is available for $125 (U.S.) $135 (Non-U.S.).

MICROCIRCUIT SCREENING DATA MDR-22A

This publication contains 375 pages of detailed microcircuit screening data used to develop the analyses of MDR-22, "Microcircuit Screening Analysis." RAC is making this data available as a separate document to enable the user to:

(1) Perform analyses that were not presented in MDR-22
(2) Examine unique part numbers or a specific set of test conditions

The data in this publication is segmented into the following test types:

- Burn-In
- Burn-In/Environmental Screening
- Single Environmental Screens
- Environmental Series Screens
- Step Stress Screens

The data contained in this publication has been extracted from the Reliability Analysis Center's Integrated Circuit Reliability Database. This data has been collected as part of RAC's data solicitation programs as well as numerous government and industry reports on the subject of microcircuit screening.

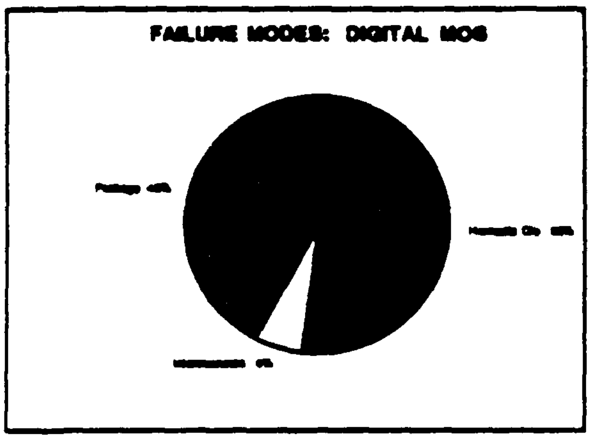
MDR-22A is available for $75 (U.S.) $90 (Non-U.S.).

MICROCIRCUIT DEVICE RELIABILITY DATABOOKS MDR-21, MDR-21A AND FMDR-21A

Field failure rates of microcircuits are an extremely important area of concern for many equipment producers.

To address this matter the Reliability Analysis Center has released an important series of new publications consisting of the **Microcircuit Device Reliability Trend Analysis, (MDR-21); the two-volume Microcircuit Device Reliability Field Experience Database (MDR-21A),** and the floppy-disk version, **FMDR-21A.**

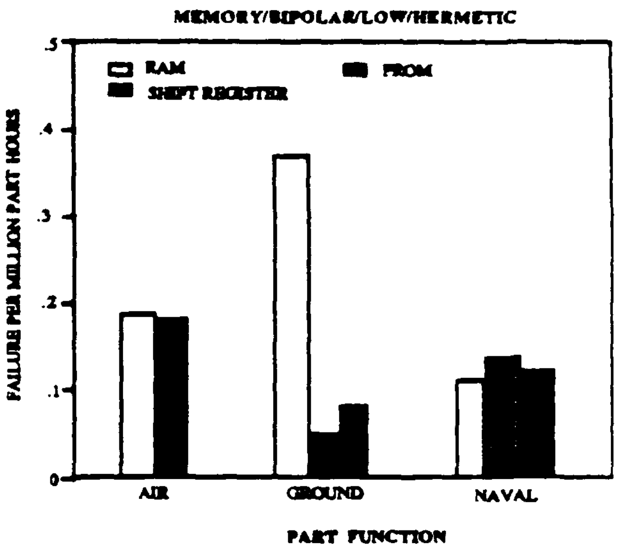
MDR-21 is a 370 page document devoted to the investigation of trends developing in microcircuit reliability. It contains evaluations of numerous microcircuit types common throughout industry, separated into generic functional groups such as: digital (SSI, MSI, and LSI), linear, interface, memories and other VLSI devices.



MDR-21A is a two-volume companion document to MDR-21. This data compendium provides detailed field failure data, including itemized part-level failure records and failure event information. The failure event section details the nature of a device failure by investigating the device characteristics and the imposed environmental or electrical stresses which were responsible for the failure occurrence.

FMDR-21A is a IBM-compatible, three-floppy-disc version of the same data found in MDR-21A. This **electronic data book** allows searches to be conducted rapidly on various data fields and the results of these custom searches to be either displayed or printed.

For added flexibility the files in FMDR-21A are in dBase III format allowing users of Ashton-Tate's dBase III to write their own data access program and report forms if desired or alternately the results of a data search may be down loaded to an ASCII text file which can be read by numerous other software packages. Furthermore the files are not **copy-protected;** this allows the data to be copied into a hard-disk and backed-up using standard DOS utilities.



MDR-21 is available for $95 (U.S.) $105 (Non-U.S.), MDR-21A $125 (U.S.) $135 (Non-U.S.), or FMDR-21A $175 (U.S.) $185 (Non-U.S.).

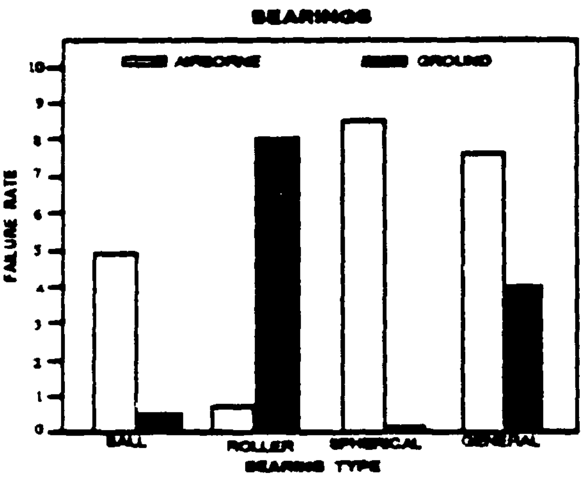
NONELECTRONIC PARTS RELIABILITY DATA NPRD-3

This 360 page document provides failure rate and failure mode information for electrical, mechanical, electro-mechanical, hydraulic, pneumatic and rotating devices.

Data appearing in this publication represents a compilation of equipment field experience in military, commercial and industrial applications.

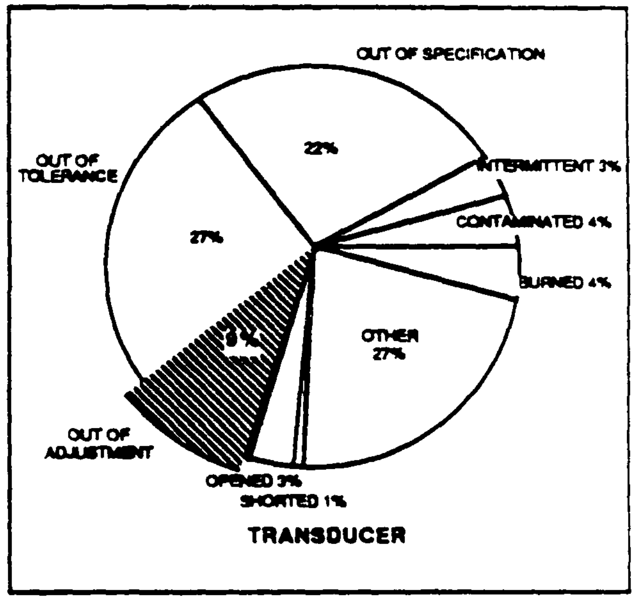
The data includes identification of part class, part type, operating environment, user, point estimate, 60% confidence interval (lower and upper), number of records merged, number of failures recorded and total of part operating hours. This information is presented in a clear and concise tabular format which makes it reliability import readily apparent.

The figures depicted are typical analyses contained in NPRD-3.



NPRD-3 is divided into four sections:

(1) background information, data limitations, assumptions and data analysis procedures
(2) generic field failure rates for a variety of operating environments
(3) detailed failure rates for selected part types
(4) failure mode distributions for various mechanical and electro-mechanical parts.



NPRD-3 is available for $80 (U.S.) $90 (Non-US).

FNPRD-3

FNPRD-3 is the diskette version of NPRD-3 data. Contained on three IBM-compatible format diskettes, it allows searches to be conducted on various data fields with the results of these custom searches either displayed or printed.

For added flexibility the files in NPRD-3 are in dBase III Plus format allowing users of Ashton-Tate's dBase III Plus to write their own data access program and report forms if desired.

As with NPRD-3 it contains identification of part class, part type, operating environment, user, point estimate, 60% confidence interval (lower and upper), number of records merged, number of failures recorded and total of part operating hours.

FNPRD-3 is available for $125 (U.S.) $135 (Non-U.S.).

ANALYSIS TECHNIQUES FOR MECHANICAL RELIABILITY NPS-1

Although the information exists for applying modern analysis techniques to nonelectronic equipment, this information, unfortunately, is widely scattered and lacks adequate standardization.

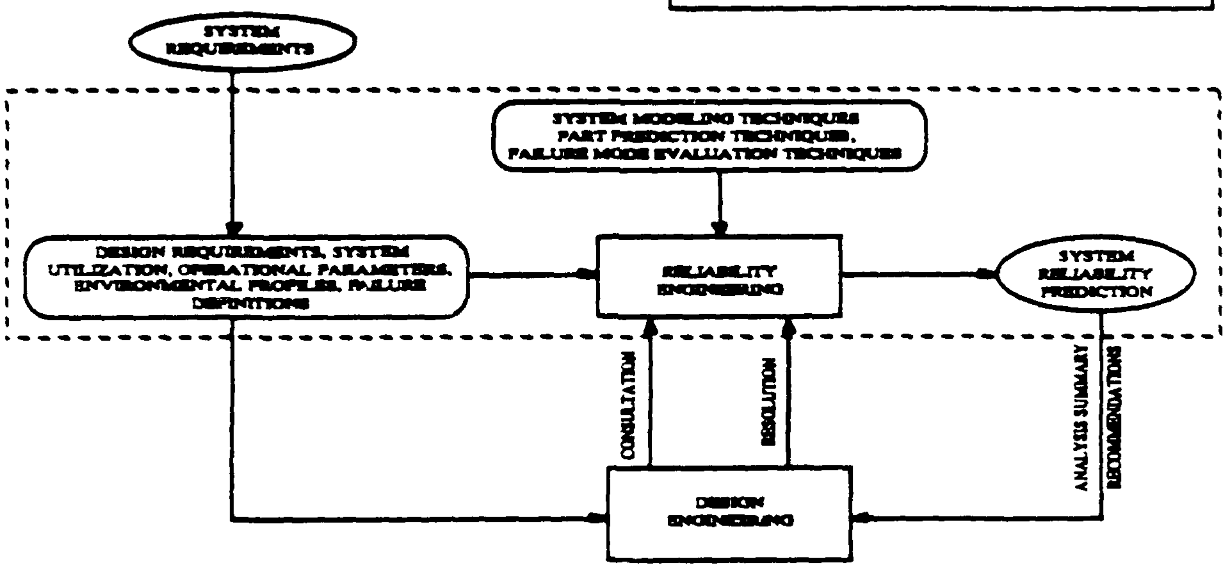
To help rectify this situation the Reliability Analysis Center has issued its first publication dedicated to the systematic application of modern analysis techniques to the reliability of nonelectronic equipment.

Analysis Techniques for Mechanical Reliability, NPS-1 is a 170 page document which is unique in the field. It provides an effective arrangement of specific material related to mechanical reliability and emphasizes the proper application of this material.

An extensive discussion of the current analysis techniques used for assessing the reliability of mechanical parts and systems is contained in Chapter 3. It provides techniques and examples for determining the quantitative estimates of performance accomplished through reliability predictions of mechanical devices. Meaningful trade-off studies can then be implemented to determine the effect on performance, cost, size, safety and weight of various designs.

BASIC PROCEDURE FOR A RELIABILITY ANALYSIS

- Characterize the System
- Apply System Configuration Methods
- Apply Part Prediction Methods
- Predict System Reliability
- Reliability Summary & Recommendations



Chapter 1 of NPS-1 presents an overview of the reliability disciplines, and a quantitative presentation of the evolution of the entire discipline.

A transition from statistical theory to reliability theory is provided next. Chapter 2 contains the fundamental aspects of statistics important to reliability including probability density functions, cumulative distribution functions and the hazard rate concept.

Chapter 4 concludes with additional remarks concerning mechanical reliability and its quantitative evaluation and identifies continuing areas of research and development.

The very important Weibull distribution is discussed in greater detail in Appendix A while Appendix B addresses the basic laws of probability.

NPS-1 is available for $56 (U.S.) $66 (Non-U.S.).

IC QUALITY GRADES: IMPACT ON SYSTEM RELIABILITY & LIFE CYCLE COSTS SOAR-3

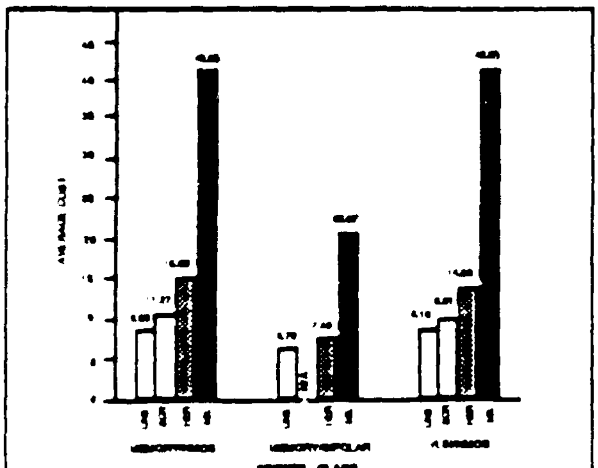
This 96 page report examines the main factors governing the relative reliability and applicability of plastic encapsulated ICs (both screened and unscreened), commercial, hermetic sealed ICs, and JAN-qualified ICs.

The reliability and applicability of commercial grade, plastic encapsulated IC's, are receiving increasing interest as the result of widespread assumptions about the present state of the microcircuit industry.

To address this important issue the Reliability Analysis Center has released **IC Quality Grades: Impact on System Reliability and Life Cycle Cost (SOAR-3).**

Topics addressed include the substantial gap between the cost of procuring commercial versus JAN-qualified parts, the lower availability of JAN parts in comparison with commercial parts, and the quality of modern plastic encapsulated devices.

The publication presents data obtained from an industry survey of IC costs and procurement lead times, a detailed discussion of these factors based upon an intensive literature search, interviews with field experts, and an examination of failure data from the RAC IC database. It then draws specific conclusions concerning the effect of part quality upon procurement cost and lead time.

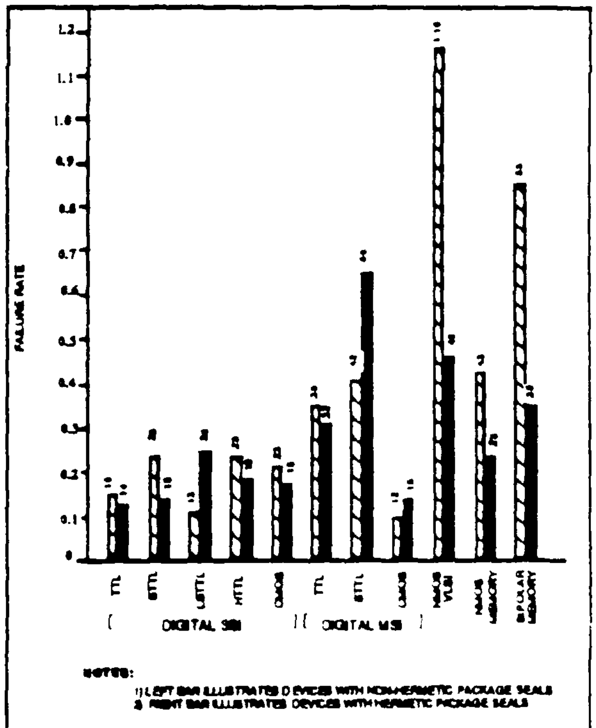


MEMORY AND MICROPROCESSOR IC's AVERAGE COST vs. SCREEN CLASS

PRIMARY AREAS OF CONCERN:

1) Initial device costs.
2) Associated procurement lead times.
3) Application stresses unique to plastic encapsulated ICs.
4) Procurement practices for obtaining the best available plastic ICs.
5) Life cycle cost analysis for alternative quality grades.

It also presents a methodology for life cycle cost estimations for alternative IC quality grades based on all of the information published in this report.



PACKAGE/TECHNOLOGY FAILURE RATES PER MILLION HOURS

SOAR-3 is available for $46 (U.S.) $56 (Non-U.S.).

SURFACE MOUNT TECHNOLOGY: A RELIABILITY REVIEW SOAR-5

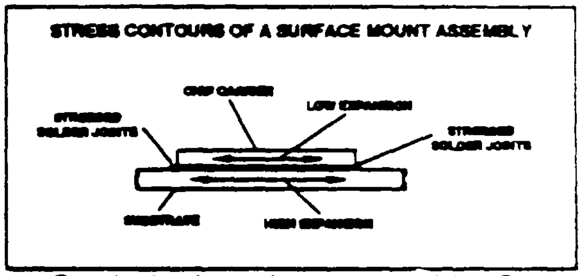
The Reliability Analysis Center's publication **Surface Mount Technology: A Reliability Review (SOAR-5)** presents an overall picture of surface mount technology, emphasizing the reliability of surface mount packaging, solder joint connections and printed wiring boards. Most of the material presented is universally applicable to a large variety of devices and device packages.

Surface Mount Technology (SMT) differs from the customary DIP through-hole assembly of electrical devices by soldering the component directly to metallized pads, or footprints, on the surface of the **Printing Wiring Board (PWB)**. The solder joint of a **Surface Mount Component (SMC)**, therefore, serves as both an electrical and a physical connection to the PWB. Since surface mounting eliminates the need for hole-drilling the smaller-dimensioned SMC's can be placed closer together and on both sides of the board, thus providing room for more component placement or simply reducing overall board size.

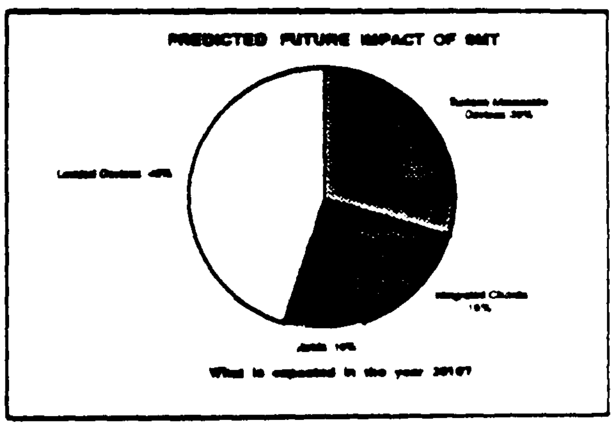
SURFACE MOUNT ASSEMBLY PROCESS STEPS

Designing for Surface Mount
↓
Component and PCB Preparation
↓
Solder Paste Deposition
↓
Component Mounting
↓
Bake Cycle
↓
Soldering
↓
Post-Solder Cleaning
↓
Testing
↓
Inspection
↓
Rework

Thermal stress results when materials with different coefficients of expansion are joined and exposed to variations in temperature. When the materials respond to thermal fluctations each at its own rate, the bond between them (the solder joint) is stressed. Damage is cumulative. The solder joint progressively weakens with thermal fluctuations and the probability of failure increases. Stresses that develop in a typical surface mount assembly containing a ceramic leadless chip carrier and an epoxy-glass substrate are depicted below:



Despite its thermal stress sensitivity, Surface **Mount Technology has emerged as the favored fabrication technique leading to the high-density, high-speed integrated circuit performance of today's microelectronics.** Manufacturing processes employed with conventional DIP componentry are being replaced by SMT, industry-wide. In cost, size, weight and performance characteristics surface mounting is better meeting the demands and competitive pressures of advancing microcircuit miniaturization.



SOAR-5 is available for $56 (U.S.) **$66 (Non-U.S.).**

ESD CONTROL IN THE MANUFACTURING ENVIRONMENT SOAR-6

Explosive growth of ESD-protective products have introduced a vast array of products for the potential buyer, thus making optimum ESD protective product selection very difficult.

To meet this challenge the Reliability Analysis Center has released the publication titled **"ESD Control In the Manufacturing Environment," SOAR-6.** This 200 page publication presents a detailed plan for the development and adaptation of a universal ESD control program. This plan can be made applicable to any manufacturing environment and to any electronic product.

SOAR-6 also explores the variety of ESD prevention products available, discusses the advantages and disadvantages of various generic products, and presents objective test methods for verifying the effectiveness of these products.

THREE MAJOR PREMISES:

All electronic parts and equipments are not equally susceptible to damage from electrostatic discharge

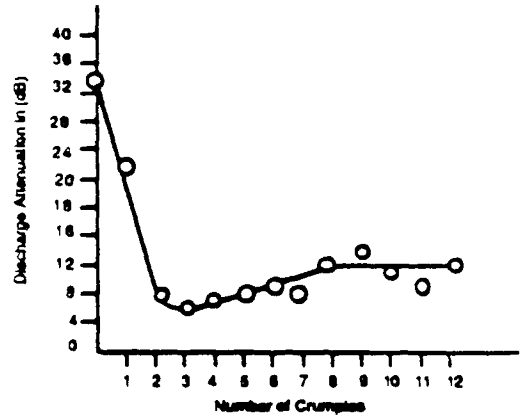
Manufacturing facilities have inherent differences

Electronic products have different intrinsic values (seriousness of the failure of the end product)

Chapter 1 defines an "ideal" ESD control program, the most comprehensive possible and adequate for critical, high-intrinsic-value electronic equipments highly susceptible to damage from ESD.

An "ideal" program would be "over-kill" for most electronic equipments. Chapter 2 establishes criteria for the tailoring of ESD requirements for electronic equipments which do not demand an "ideal," high-cost, program of ESD protection and control.

A variety of generic products are often available to fulfill a specific ESD-protection requirement. Not all of these products would be equally effective in the accomplishment of that requirement. Some generic products may be very effective in a given situation but may degrade with use, or they may be ineffective under different circumstances.



TYPICAL LIFE TEST RESULTS

Chapter 3 addresses the strengths and the weaknesses of various generic products and provides guidance regarding instances in which a given generic product may not be effective in meeting a specific ESD-protection requirement.

Significant variations exist within generic products, both between different manufacturer's products and within a given manufacturer's product line. Chapter 4 defines specific product qualification and acceptance tests for various ESD protective materials. It also defines an ESD control program monitoring plan.

Appendix A includes information on a number of electrostatic discharge video tapes currently available for ESD education and awareness training.

Appendices B and C contain sample copies of proposed detail test methods for some of the primary generic ESD protection materials and equipments.

SOAR-6 is available for $56 (U.S.) $66 (Non-U.S.).

STATE-OF-THE-ART REPORTS

PRACTICAL STATISTICAL ANALYSIS FOR THE RELIABILITY ENGINEER
SOAR-2

This document consists of a series of "stand-alone" chapters which comprise an elementary text on statistical methods applicable to reliability studies and data analysis. Aimed at the non-specialist, the text explains a variety of statistical methods and covers both parametric and non-parametric methods. Practicing reliability engineers are also aided in selecting and using appropriate analytical methods. SOAR-2 is written in understandable language with a minimum of esoteric mathematics. Graphs, tables and clear, explanatory prose strip away statistical mystique. 1983, 180 pages. **SOAR-2 is available for $36 (U.S.) $46 (Non-U.S.).**

CONFIDENCE BOUNDS FOR SYSTEM RELIABILITY
SOAR-4

This study supplies algorithms for estimating confidence bounds on system reliability from subsystem reliability estimates. Four theoretical methods are compared through a simulation study; these methods are suitable for use in conjunction with subsystem-level fixed sample reliability tests (as described in MIL-STD-781, "Reliability Tests and Exponential Distribution)." Standard procedure for estimating and simulating confidence bounds removes the ambiguity often faced by project offices and allows maintenance units to effectively plan support needs. This text is oriented toward non-statisticians. 1985, 200 pages. **SOAR-4 is available for $46 (U.S.) $56 (Non-U.S.).**

EQUIPMENT DATA PUBLICATIONS

ELECTRONIC EQUIPMENT RELIABILITY DATA
EERD-2

This publication evaluates system/equipment level reliability. The compendium contains data on military electronic equipments at the set, group and unit levels derived from the RAC's dedicated data base. This data base contains specific information on the contractual and technical descriptions of equipment reliability, availability and maintainability. The primary objective of the document is to provide sufficient information for the evaluation of common reliability practices as well as for the investigation of those parameters designed to assist in the development of reliable equipments. Further, the data helps to refine, revise and develop reliability and maintainability prediction, allocation and demonstration techniques with regard to the environment and type of equipment. 1986, 400 pages. **EERD-2 is available for $80 (U.S.) $95 (Non-U.S.).**

ELECTRONIC EQUIPMENT MAINTAINABILITY DATA
EEMD-1

This compendium contains maintenance and repair time data on military electronic equipments at the subsystem, set, group and unit levels. The document presents a variety of detailed equipment level maintainability data to assist in the effective evaluation of equipment field reliability. The information is given to facilitate the tracking of an equipments maintainability characteristics throughout its life cycle as well as to provide a baseline for comparison among similar equipments. 1980, 310 pages. **EEMD-1 is available for $60 (U.S.) $70 (Non-U.S.)**

SEARCH AND RETRIEVAL INDEXES

IRPS PROCEEDINGS • 1968 to 1978 • 1979 to 1984
TRS-2 and TRS-2A

These volumes provide rapid location of papers on various topics published in IRPS Symposium Proceedings. The papers encompass the most up-to-date work performed to enhance our understanding of electronic device physics of failure. Four types of indexes are employed including: authors, corporations, subjects, and index terms. Within the chronological listing of all papers the detailed index terms provide an overview of the intent and depth of each paper. TRS-2A, 1984, 210 pages, TRS-2 1979, 385 pages. **TRS-2 and TRS-2A are available for $24** (U.S.) **$34** (Non-U.S.).

EOS/ESD TECHNOLOGY ABSTRACTS • 1982
TRS-3A

This document provides a comprehensive bibliography of literature pertaining to electrical overstress and electrostatic discharge damage. Reference to the degradation of electronic devices encompasses design, failure analysis, protective measures/techniques and training programs. The references were selected from the Reliability Analysis Center's document files which include acquisitions made from 1967 to 1982. Documents were selected for currency, usefulness and availability. 1982, 287 pages. **TRS-3A is available for $36** (U.S.) **$46** (Non-U.S.).

EOS/ESD PROCEEDINGS • 1979 - 1984
TRS-4

This document provides quick access to articles published in the annual EOS/ESD Symposia from 1979 to 1984. Papers published in the Proceedings represent the most current studies and information available on the effects of EOS/ESD phenomena on electronic devices. Indexes include an alphabetical listing of terms, subjects, authors, corporations, keywords in the title and a chronological list of papers. 1985, 133 pages. **TRS-4 is available for $36** (U.S.) **$46** (Non-U.S.).

ISTFA PROCEEDINGS • 1978 - 1985
TRS-5

This publication makes information retrieval from the International Symposium for Testing and Failure Analysis (ISTFA) Proceedings an efficient procedure. Information is included on every article printed in the eight-year span of ISTFA Proceedings, and that information is separated into six different retrieval categories: abstracts, alphabetical listing of index terms, author, chronological lists of papers, corporation, keywords in title, and subject. 1986, 377 pages. **TRS-5 is available for $36** (U.S.) **$46** (Non-U.S.).

TRAINING COURSES

DESIGN RELIABILITY TRAINING COURSE

1. Do you have an adequate understanding of the mathematical basis of reliability theory?

2. Do you have a working knowledge of Reliability Apportionment, Prediction & Modeling?

3. What is the essential difference between the "Basic" and the "Mission Reliability" Model?

4. What is the purpose of a FMECA, what type of questions does a FMECA address?

5. Given the FMEA for a simple system, what additional data would you need to complete the CA and identify criticality relationships among the parts?

6. Define the following terms: α, β, PRST, discrimination ratio (DR), confidence interval.

7. What is the difference between Qualification Testing and PRAT? What stressing functions are used during these tests?

8. Do you have a working knowledge of the following?
   a) MIL-STD-781D & MIL-HDBK-781?
   b) MIL-STD-756 & MIL-HDBK-217?
   c) MIL-STD-2155 & MIL-HDBK-189?
   d) MIL-STD-810?

9. Given applicable data, could you plan a Reliability Demonstration Test and estimate the amount of time needed to complete the test?

10. What is the main purpose for derating? How is it accomplished with various part types?

11. What is the essential difference between the Weibull and the Exponential Distribution?

12. Can you perform a detail stress prediction for a typical microcircuit?

13. How do you quantify the reliability impact of different quality grades of parts?

14. What is the primary underlying assumption upon which part screening is based?

15. What are some of the various forms of redundancy and what are their relative merits?

16. What can be done to a circuit to compensate for component drift and other parameter variations?

17. What is a "Schmoo Plot" and how is it used?

18. What are some of the principal methods for dealing with EMI and electrical transients?

19. What is a Sneak Circuit Analysis and how can it assist the reliability engineer?

20. What is the basic cause of ESD? What types of components can be damaged?

21. Name the primary tool for preventing ESD damage.

22. How does Fault Tree Analysis differ from FMEA?

23. What are cut-sets? When and how are they used?

24. What is the purpose of FRACAS and how does it function in Reliability growth?

25. How do different manufacturing methods and maintenance concepts impact equipment reliability?

26. What are the four major elements of Testability?

27. What is the difference between BIT and BITE?

28. What is the purpose of ESS and what primary stresses are used to accomplish it?

29. How is "Tailoring" of MIL-STD-785 task requirements accomplished?

If you were unable to answer a good portion of these questions perhaps you need the Reliability Analysis Center's Design Reliability Training Course. For further information on this or other RAC training courses please contact: Mr. James W. Wilbur at (315) 337-0900.

NOTE: Military Agencies may use DD Form 1556 for ordering an on-site course presentation.

PRACTICAL STATISTICAL ANALYSIS WITH RELIABILITY APPLICATIONS TRAINING COURSE

Recognizing the need for and prevalence of statistical approaches used in the transmittal of information in today's engineering world, the Reliability Analysis Center (RAC) has prepared the tutorial entitled **"Practical Statistical Analysis with Reliability Applications."**

This intensive four-day course which is presented only in a private, "on-site" mode at a venue supplied by the customer, has been structured specifically to help the nonstatistician who needs to apply statistical methods or understand their use in technical reports. It introduces the non-specialists to statistical concepts with a minimum of mathematics and explains (by example) some popular methods applicable to practical reliability studies. It also provides a basic understanding of the statistics commonly used in technical reports and supplies the background and references for more advanced methods, while indicating their potential.

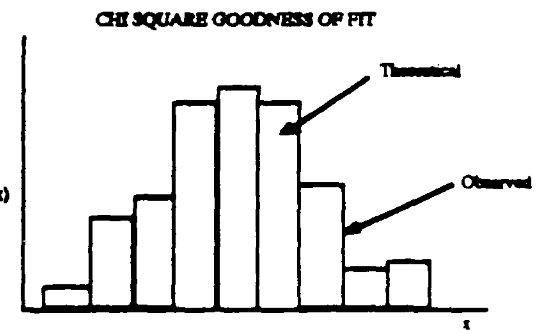
Major Course Components

- Review of probability theory and basic statistics; confidence intervals
- Theoretical distributions; statistical tables; non-parametrics; analysis of variance
- The correlation coefficient
- Regression analysis
- Reliability distributions and influences
- Weibull plotting; goodness-of-fit tests
- Life testing; reliability demonstration tests
- Sampling inspection; reliability growth

Because this tutorial presents a vast volume of material in a short time, the RAC considers engineering mathematics to degree level to be a prerequisite for attendance at this course. In addition, an elementary course (or reading) in basic probability or statistics would be an advantage.

Course Format

The course is divided into eight four-hour sessions, which run from 8:00 a.m. to noon and from 1:00 p.m. to 5:00 p.m. Evening study in solving exercises and reading the text will be necessary. Each section includes lecture material and student participation in examples, projects, and demonstration. The course also includes the use of personal computers with a menu-driven statistics package, "The Statistician," developed by Quant Systems.



GOODNESS OF FIT - HISTOGRAM AGAINST p.d.f.

The course is structured for applications and as such does not develop underlying theory from first principles. Each subject area is developed using actual reliability studies on failure analysis data.

For further information on this or other RAC training courses, please contact Mr. James Wilbur at (315) 337-0900.

NOTE: Military Agencies may use DD Form 1556 for ordering an on-site course presentation.

TESTABILITY PRACTICES TODAY TRAINING COURSE

Does this question sound familiar? Very likely the cause of the problem lies in the fact that the equipment was not designed with testability in mind.

It has long been recognized that if the inherent testability of the design is not addressed right from the very start of the program it will be physically impossible to later meet specific BIT requirements for the equipment.

The RAC training course **"Testability Practices Today"** (TPT) is specifically intended to provide procedural guidelines designed to meet just this need. This course helps you to address the inherent testability characteristics of your equipment beginning at the conceptual design stage and progressing right straight through to design completion.

SELECTED COURSE TOPICS

ATE Techniques & Strategies

Digital Guidelines for Testability

VLSI Guidelines for Testability

Surface Mount Technology Testability Guidelines

Analog Guidelines for Testability

IEEE Standard Testability Bus

MIL-STD-2165

Testability Rating Systems

This intensive three day state-of-the-art seminar is designed to acquaint attendees with the very latest techniques for designing testability into your equipment. The course addresses both analog and digital designs and is equally applicable to both military and industrial/commercial equipments. It is designed to demonstrate the importance of direct, open and useful communication among design engineering, test engineering and management personnel to provide the vital feedback link to make testability work in an organization.

The TPT addresses the means by which to accomplish increased productivity within each functional operation as well as within the total business organization, and demonstrates measurable cost savings achievable through reduced test programming, fixturing, equipment, execution and troubleshooting efforts.

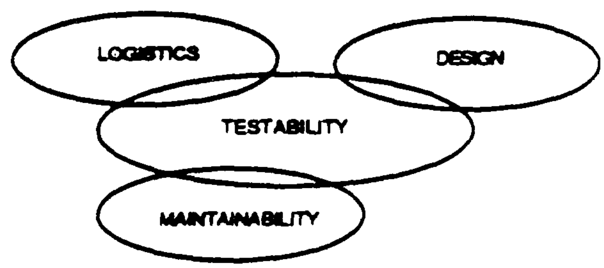
Examples are given of two test strategies employed at the board level. Major cost elements, including capital, fixturing, programming, diagnostics and system diangostics illustrate conditions in which (a) in-circuit test or (b) dynamic functional test provides greater cost saving.

Example #1 is based on 100 parts per PCB, 10 PCB's per system and 1000 systems produced per year, 2.5 faults per board, a system yield of 85% for in-circuit test and 95% for functional test, and a system cost per fault of $25.00. Example #2 differs only in considering 50 PCB's, 5000 systems per year and a cost per fault of $50.00. Example #1 demonstrates a $345K saving using in-circuit test. Example #2 demonstrates a $525K saving using functional test.

In general, the choice between the two strategies reflects the increase in cost for fault-finding at the system level due to the greater complexity of one of the two systems compared.

By combining lecture and workshop tutorial techniques it provides each participant with the knowledge necessary to design and implement a testability program within a specific organization.

TESTABILITY BRIDGES THE GAP BETWEEN DISCIPLINES



For further information on this or any of the other Reliability Analysis Center Training Courses please contact: Mr. James Wilbur at (315) 337-0900.

NOTE: Military Agencies may use DD Form 1556 for ordering an on-site course presentation.

STATISTICAL PROCESS CONTROL TRAINING COURSE

The term **Statistical Process Control (SPC)** strictly refers to the use of charting techniques (i.e. control charts, Pareto diagrams, etc.). Of late, however, the term SPC has been used to describe the total philosophy of quality management and continuous improvement. Many organizations call it **Quality-Productivity Improvement (QPI).**

The Reliability Analysis Center has prepared the training course entitled **Statistical Process Control** which is presented four times a year throughout the U.S. on an open-to-the-public basis.

This concentrated four-day course presents a combined management/statistical approach to designing, measuring and controlling high-quality processes, products and services. It uses objective techniques based on data to support management decisions and is applicable to all businesses. It employs powerful statistical methods to separate assignable causes of process variability from random causes. The overall goal is continuous improvement of the process and the product, driving toward zero defects.

The statistical techniques of SPC have been available since the 1920s; the impetus for the current drive to SPC has been W. Edwards Deming's management philosophy, within which the statistical techniques are fully integrated.

Rather than using the traditional approach for setting arbitrary tolerances and rejecting (or applying for QC waivers on) out-of-specification products, SPC bases tolerances on a sophisticated analysis of process data (called a "process capability study"). Effort then concentrates on reducing process variability by process, system, or management improvements. In this way, tolerances are implicitly reduced.

SPC recognizes that traditional approaches to quality (such as inspection, procedures, etc.) generally serve to reduce quality, since responsibility for excellence is divided between worker and inspector. SPC argues for quality personnel to be integrated into manufacturing to improve the process before defects occur. This is the basis of "doing it right the first time" as opposed to paying one worker to produce a defect and a second to catch it.

Course content and length can be modified within limits to suit the customer's needs.

There are no mandatory homework assignments nor are students graded competitively. However, there are voluntary homework problems and the students will receive a certificate of course completion at the end of the presentation.

RAC also offers an on-site training program customized to teach actual examples and case studies from the customer's own organization. The program concentrates on problem solving and is taught at three or four levels, as follows:

1. Top management
2. Middle management, supervisor, staff specialists, engineering support, etc.
3. Workers, operators, technicians
4. QPI team seminars

Reliability Analysis Center's "Seven Steps to Effective Problem Solving"

Step 1: Identify Key Problems

Step 2: Specify Customers and Their Requirements

Step 3: Quantify the Variables

Step 4: Quantify and verify the Cause and Effect Relationships

Step 5: Optimize the Process and Confirm the Results

Step 6: Define Operating Requirements of the Acceptable Process

Step 7: Institute Control Procedures for Problem Prevention

For further information on this or any other RAC training courses, contact Mr. James Wilbur at (315) 337-0900.

NOTE: Military agencies may use DD Form 1556 for ordering an on-site course presentation.

PRODUCT FEE SCHEDULE

		Price Per Copy U.S.	Non-U.S.
	COMPONENT RELIABILITY DATABOOKS		
DSR-4	Discrete Semiconductor Device Reliability - 1988	100.00	120.00
NPRD-3	Nonelectronic Parts Reliability Data 1985 - (Printed Copy)	80.00	90.00
FNPRD-3	Diskette of NPRD-3 Data (IBM PC Compatible)	125.00	135.00
VZAP-2	Electrostatic Discharge Susceptibility Data - 1989	125.00	135.00
MDR-21	Trend Analysis Databook - 1985	95.00	105.00
MDR-21A	Field Experience Databook - 1985	125.00	135.00
FMDR-21A	Diskette of MDR-21A Data (IBM PC Compatible)	175.00	185.00
MDR-22	Microcircuit Screening Analysis - 1987	125.00	135.00
MDR-22A	Microcircuit Screening Data - 1987	75.00	90.00
NONOP-1	Nonoperating Reliability Data - 1987	150.00	160.00
	EQUIPMENT DATABOOKS		
EERD-2	Electronic Equipment Reliability Data - 1986	80.00	95.00
EEMD-1	Electronic Equipment Maintainability Data - 1980	60.00	70.00
	HANDBOOKS		
RDH-376	Reliability Design Handbook	36.00	46.00
MFAT-1	Microelectronics Failure Analysis Techniques Procedural Guide	125.00	135.00
NPS-1	Analysis Techniques for Mechanical Reliability	56.00	66.00
PRIM-1	A Primer for DoD Reliability, Maintainability and Safety Standards	95.00	115.00
	PRODUCTS FOR PERSONAL COMPUTERS		
RAC-NRPS	Nonoperating Reliability Prediction Software (Price includes NONOP-1 listed above)	1400.00	1450.00
	STATE-OF-THE-ART REPORTS		
SOAR-2	Practical Statistical Analysis for the Reliability Engineer	36.00	46.00
SOAR-3	IC Quality Grades: Impact on System Reliability and Life Cycle Cost	46.00	56.00
SOAR-4	Confidence Bounds for System Reliability	46.00	56.00
SOAR-5	Surface Mount Technology: A Reliability Review	56.00	66.00
SOAR-6	ESD Control in the Manufacturing Environment	56.00	66.00
	TECHNICAL RELIABILITY STUDIES		
TRS-2	Search and Retrieval Index to IRPS Proceedings - 1968 to 1978	24.00	34.00
TRS-2A	Search and Retrieval Index to IRPS Proceedings - 1979 to 1984	24.00	34.00
TRS-3A	EOS/ESD Technology Abstracts - 1982	36.00	46.00
TRS-4	Search and Retrieval Index to EOS/ESD Proceedings - 1979 to 1984	36.00	46.00
TRS-5	Search and Retrieval Index to ISTFA Proceedings - 1978 to 1985	36.00	46.00

ADDITIONAL RAC SERVICES

Literature Searches

Literature Searches are conducted at a flat fee of $50. For best results, please call or write for assistance in formulating your search question. An extra charge, based on engineering time and costs, will be made for evaluating, extracting or summarizing information from the cited references.

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APPENDIX B

SEPTEMBER 1988 RAC NEWSLETTER

RAC Newsletter

RELIABILITY ANALYSIS CENTER

September 1988

RELIABILITY: WHERE ARE THE UNIVERSITIES?

Professor Marvin L. Roush
Director, Center for Reliability Engineering
University of Maryland

I have heard it said that newly graduated engineers from our U.S. universities seem to have had no exposure to measures of reliability, let alone be capable of designing components or systems with reliability in mind.

My observations support this assertion to a large degree, and I have puzzled over the question of whether the universities are failing to do their job or whether the expectation is inappropriate for universities. In a time when "national competitiveness" is an important issue and the Defense Department claims that system reliability and availability are critical, it would seem that integrating reliability considerations into design would be given careful attention at all levels. Why, then, is it not so in university engineering education and what forces are at work which inhibit the integration of reliability considerations into all of engineering education?

While some aspects of quality control receive excellent attention as part of university programs, dealing with manufacturing and reliability seems to be the center of focus in highly mathematical approaches to statistical test planning and in data analysis using Weibull distributions and Bayesian techniques, the weakness seems to be in the engineering design area. It is my premise that there are few university engineering faculty who would be comfortable teaching reliability considerations within their particular special discipline. With their limited knowledge about reliability, they would find it difficult to select homework problems and design problems which incorporate reliability, let alone grade the solutions.

I personally have concluded that there is a real need for giving attention to the inclusion of reliability considerations within engineering education. Reliability is at least as important in product acceptance as performance against mission objectives and cost. The Air Force "R&M 2000" program recognizes this. How, then, can universities claim to be teaching engineering and economic fundamentals without recognizing the important third leg of the stool? The answer is that engineering education is incomplete without inclusion of reliability in the curriculum.

A careful look at the climate in which a young faculty member strives to attain tenure within the university community offers some understanding of the origin of this failure. A primary consideration of successful performance of the faculty member is the number and quality of published articles in prestigious journals. Another important factor is a demonstration of the

INSIDE

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person's capability to attract significant funding to support his/her research program. At times, consideration is given as well as to the prestige of the source of research funds, e.g., National Science Foundation funding is usually considered an indication that the person is among a somewhat select national group of researchers within a particular discipline. The average engineering faculty member looks about and does not see a focus upon reliability at the NSF, does not see the DoD establishing centers of excellence in reliability at selected universities, does not see industrial and government efforts to involve universities in reliability research efforts, and does not see a broad range of good materials to aid in teaching reliability considerations within each of the various engineering disciplines. It then appears that integration of reliability into engineering is not very important nationally and not an area on which to base one's professional career.

Persons outside of universities can help create a climate in which faculty will be interested in investing their time in learning more about reliability engineering by changing the perceived opportunities in the discipline. Universities can and will respond to the need to add a focus on reliability throughout engineering if they find that their efforts are reinforced by actions within government and industry. The formation of a Center for Reliability Engineering at the University of Maryland is a formal effort of one school to indicate its commitment to work closely with both government and industry in this endeavor. In addition, our academic program leading to MS or PhD degrees in reliability engineering responds to a part of the need. Even at Maryland, much room for improvement exists in the incorporation of reliability in the undergraduate engineering curriculum. I challenge you to enlist in university faculty to help solve your problems. You will benefit as will the nation's future engineers.

INDUSTRY UPDATE

RADC RELIABILITY ENGINEER'S TOOLKIT

Rome Air Development Center (RADC) has developed and published an application oriented guide for the practicing reliability engineer entitled "RADC Reliability Engineer's Toolkit." This 200+ page document was written by several members of the Systems Reliability and Engineering Division based on their combined experience in developing R&M techniques and in providing R&M engineering support to Air Force system development programs. The main sections of the document follow the flow of a normal development program, from determination of requirements to testing. Twelve appendices give a greater level of detail to some of the topics in the main sections and also provide useful reference materials. Examples of the subjects addressed are:

- R&M Task Priorities
- Part Stress Derating
- Design Review Questions
- Critical Item Checklists
- Reliability Prediction Methods
- Redundancy Equations
- Reliability Demonstration Plan Selection
- Warranty Guidelines
- R&M Data Sources
- R&M Education Sources
- AF R&M Focal Points

While the Toolkit's title says its content is reliability, a broad interpretation of the term has been taken to include maintainability and testability. Emphasis is on what the engineer's role is in the particular process. For example, what issues should be raised at design reviews, and what is the significance of contractor response?

A copy of the Toolkit may be obtained by written request to RADC/RBER, ATTN: RADC Toolkit, Griffiss AFB, NY 13441-5700.

COMING UP - THE 10th ANNIVERSARY OF THE EOS/ESD SYMPOSIUM

Roy C. Walker
Co-Chairman 1979 EOS/ESD Symposium

At the August 31, 1978 planning meeting, it took three hours of arguing to arrive at a consensus to call the "EOS/ESD Symposium" Electrical Overstress/ElectroStatic Discharge Symposium by its present name. Coming up to the tenth symposium, it seems the name has not been much of a hindrance.

There have been nine annual symposia since 1979. Each symposium has produced a proceedings, providing industry with valuable reference tools. Attendees could ask the paper presenters questions and even challenge their conclusions. From the start, each symposium has had exhibitors because of the need to identify products useful to prevent ESD phenomena and to discuss product applications and specifications in a technical setting.

The 10th symposium is being held at the Anaheim Marriott, located beside the Anaheim Convention Center and Disneyland. The technical presentations will be given to an audience expected to reach 1000. Over 100 booth spaces have been constructed in a room adjacent to the technical sessions. For attendees interested in training videotapes, the most popular videotapes will be available for viewing throughout the symposium.

The technical program begins Tuesday morning, September 27th, with a keynote address given by Owen McAteer on the progress in ESD over the decade the symposium has been held. Following the keynote address will be a session covering EOS/ESD field failures in military equipment, factory training programs, a case history

RELIABILITY GROWTH ANALYSIS USING THE DUANE AND AMSAA MODELS

Reliability Growth Testing (RGT) implemented with a Test-Analyze-And-Fix (TAAF) process is becoming an increasingly popular and effective reliability assurance technique. The objective of RGT is to test a system or equipment in an environment similar to its operational one, analyze any failures that occur during the test and implement design changes if they are appropriate. The TAAF portion is where the reliability improvement actually originates. Unlike other R/M tests the purpose of RGT is to precipitate failures. As with many reliability and maintainability (R/M) techniques, RGT should be part of the development process.

RGT is required and regulated by many DoD handbooks and standards, including MIL-STD-785B, "Reliability Program for Systems and Equipment, Development and Production," MIL-HDBK-189, "Reliability Growth Management;" and MIL-STD-1635, "Reliability Growth Testing." An excellent guide to the practical aspects of RGT and TAAF is the publication "Best Practices," available from the Department of the Navy, NAVSO P-6071. In each phase, new and useful information from failure analysis can be implemented in the form of corrective actions that improve the reliability of the equipment. To measure the effectiveness of design fixes, models have been developed to determine if the mean-time-between-failures (MTBF) of the equipment is in fact "growing."

There are many models available to analyze growth data. Two of the most widely used are the Duane model, developed by J.T. Duane of General Electric in 1962, and the Army Material Systems Analysis Activity (AMSAA) model, developed by Dr. L.H. Crow in 1972. The Duane model is based on an empirical relationship that as long as the MTBF is growing the following holds:

$$MTBF_{cum} = \frac{1}{K} T^{\alpha}$$

where:

$MTBF_{cum}$	=	Cumulative MTBF
K	=	Constant determined by the initial MTBF
α	=	Growth rate (the slope of the log-log plot of $MTBF_{cum}$ vs Test Time)
T	=	Cumulative test time

In most cases, the log-log plot of cumulative failures vs. test time will result in a linear relationship if the system reliability is improving due to a test-analyze-and-fix (TAAF) procedure. The TAAF procedure improves system reliability based on the incorporation of design changes. If the slope of the best fit line of such a plot is positive, the system is said to be growing in reliability as time progresses, hence the term "reliability growth."

The Duane model assumes that the design fixes are 100% effective and that they are implemented immediately. From this established cumulative MTBF an instantaneous MTBF can be calculated. The instantaneous MTBF ($MTBF_{inst}$) is the MTBF of the design, assuming there are no further design changes and that the design changes that did occur were implemented successfully.

The instantaneous MTBF is calculated:

$$MTBF_{inst} = \frac{MTBF_{cum}}{(1-\alpha)}$$

Usually the plot of $MTBF_{cum}$ and $MTBF_{inst}$ results in two linearly increasing parallel lines on log-log paper as shown in Figure 1. The instantaneous MTBF essentially estimates the projected field failure rate by accounting for fixes without purging the failure data.

RAC

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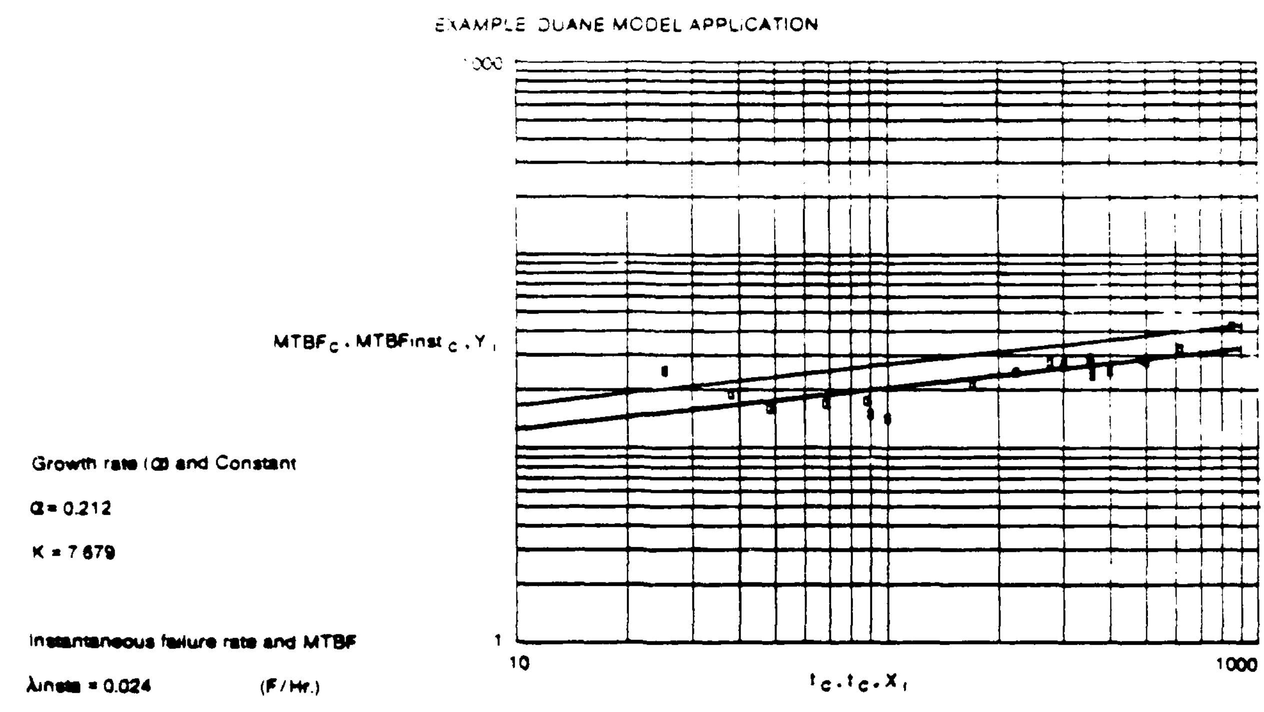

Figure 1: Plot of Duane Model

The Duane model assumes that growth is a deterministic process, while the AMSAA model views the process of reliability growth as a probabilistic process. The AMSAA model is based on the empirical relationship developed by Duane and is equivalent to a non-homogeneous Poisson process model with a Weibull intensity function. The AMSAA model is:

$$r_c(t) = \lambda t^{\beta-1}$$

where:

- $r_c(t)$ = The cumulative failure rate at time t
- t = Total test time
- β = Estimate of the time value of the growth parameter
- λ = Scale parameter

The instantaneous failure rate $r_i(t)$ at time t is the incremental change in number of failures (F) with respect to the change in time. It is derived in the following manner:

(i) $\frac{F}{T} = r_c(t) = \lambda t^{\beta-1}$

(ii) $F = \lambda t^{\beta}$

(iii) $\frac{dF}{dT} = \lambda\beta t^{\beta-1} = r_i(t)$

(iv) $\therefore \beta r_c(t) = r_i(t)$

It can be seen that the parameter α used in the Duane Model is equivalent to $(1-\beta)$ of the AMSAA model. Note that the AMSAA model is based upon failure rate estimates, whereas the Duane model is based upon MTBF estimates.

The form of the AMSAA model used on a particular set of data is based on two issues concerning the test data. First, did the test end with a failure? If it did, the test is considered to be a failure truncated test. If the test did not end with a failure, it is considered to be a time truncated test. Second, if fewer than 20 failures occurred

during the test, it is appropriate to use unbiased estimates for $r(t)$; otherwise, the biased estimates are used. The large sample (biased) estimates for β and λ are:

$$\hat{\lambda} = \frac{N}{t_o^{\hat{\beta}}} \qquad \text{where:} \qquad \hat{\beta} = \frac{N}{M \ln(X_n) - \sum_{i=1}^{M} \ln(X_i)} \qquad \text{or} \qquad \hat{\beta} = \frac{N}{N \ln(t_o) - \sum_{i=1}^{N} \ln(X_i)}$$

Failure Truncated Time Truncated

The small sample (unbiased) estimates for β and λ are:

$$\bar{\lambda} = \frac{N}{t_o^{\bar{\beta}}} \qquad \text{where:} \qquad \bar{\beta} = \frac{N-2}{N}\hat{\beta} \qquad \text{or} \qquad \bar{\beta} = \frac{N-1}{N}\hat{\beta}$$

Failure Truncated Time Truncated

N is the total number of failures, $M = N-1$, t_o is the total test time, X_i are the individual failure times, X_n is the time of the last failure.

The data points and the cumulative and instantaneous failure rates are plotted on log-log paper. Figure 2 is an example of the AMSAA model fitted to some actual growth test data. The data are the actual individual Times-To-Failure (TTFs) of the system under test. The TTFs (in hours) plotted are: 25, 38, 48, 68, 88, 90, 100, 170, 222, 275, 300, 350, 355, 357, 357, 399, 490, 500, 620 and 850.

EXAMPLE: AMSAA MODEL APPLICATION

$$\lambda HTT \cdot \left[TX_k^{(\beta HTT-1)} \right] \cdot \lambda HTT \cdot \beta HTT \cdot \left[TX_k^{(\beta HTT-1)} \right] \cdot \frac{1}{X_i}$$

Time Truncated Case

μTT = -2.838 HTT = Biased estimates

CM2TT = 0.287 BTT = Unbiased estimates

α (growth rate)

αHTT = -0.348 αBTT = -0.379

Instantaneous failure rate & MTBF

rHTT = 0.015 (F/Hr.)

rBTT = 0.014 (F/Hr.)

BHTT = 68.852 (Hrs.)

BBTT = 72.476 (Hrs.)

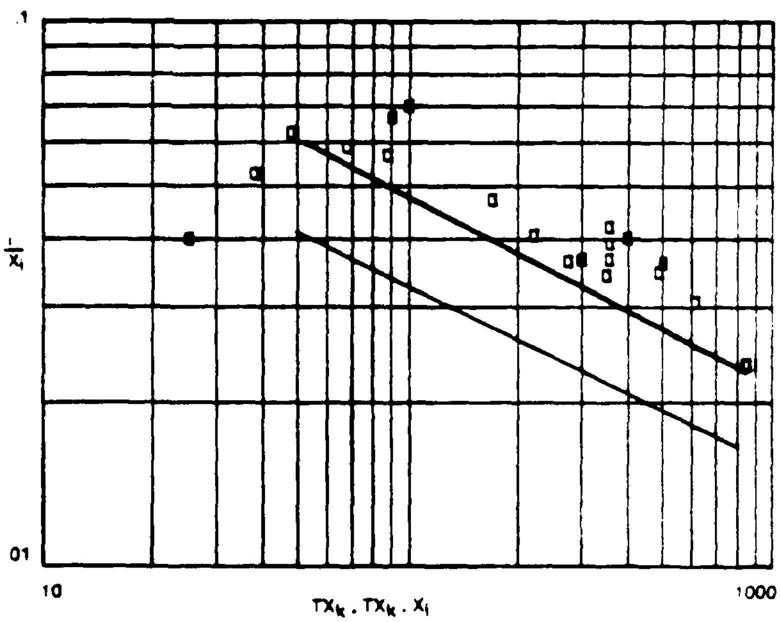

Figure 2: Plot of AMSAA Model

The slight hook at the beginning of the graph shows a low failure rate until the early defects have had time to reveal themselves. This is sometimes due to a burn-in-like effect. It is also interesting to note that the model does not appear to fit exactly through the center of the data points as the least squares estimate would. This is because the AMSAA model takes into account the exponential relationship between each data point. The line, therefore, is a more accurate representation of the reduction in failure rate with respect to time.

Because the testing did not conclude with a failure, the time truncated formulas were applied to the data. The instantaneous estimates for failure rate and MTBF were calculated using both the biased and unbiased techniques, because the sample size is right at the 20 point limit. The unbiased MTBF is 72 hours while the biased is 68 hours. By statistical definition if the sample size is 20 or below the unbiased estimate should be used. Using the unbiased estimate of 72 hours MTBF, an upper and lower confidence bound can be calculated using the tables from MIL-HDBK-189. For a sample size of 20 at a 90% level of confidence the bounds are defined by .6601 X MTBF < MTBF < 1.918 X MTBF. Therefore, the confidence interval for this example is 48 hours to 138 hours, i.e., we are 90% confident that the actual MTBF is between 48 and 138 hours.

The trend statistic, μ_{TT}, determines the presence of any significant trends in failure rate. In this example $\mu_{TT} = -2.838$. By comparing this to the tables in MIL-HDBK-189 it was determined that there is a 99% probability that the failure rate is decreasing. Though it is obvious in this example, it is not always so clear. The accept or reject criteria for the model is based on the C_m2 statistic. After computing this statistic it is compared to the C_m2 table in MIL-HDBK-189. In this example it supports the 90% confidence level in favor of accepting the fitted model, i.e., we are 90% confident the model fits the data.

Another issue surrounding the analysis of RGT data concerns the chargeability of failures. In general, all failures are chargeable unless they are induced by some outside unrelated source. If the data is incorrectly altered by what some consider nonchargeable failures, then improper growth rate estimates will result. A failure review board (FRB) should be established to determine what failures are chargeable and to assign responsibilities to appropriate individuals regarding proposed corrective actions. The board should meet on a regular basis during the RGT. In most cases, the RGT will stop for the entire process of correcting failures. Beware of the claim that "the design fix will be incorporated during the production phase." The design fix should be implemented on the equipment under test before the test resumes.

In March 1988 the Institute of Environmental Sciences (IES) presented a reliability growth management conference. The conference organizing committee issued a list of recommended practices based on the cumulative knowledge of many leaders in the field. A condensed version is presented here.

RECOMMENDED PRACTICES

1. Top management support is essential
2. Reliability growth is part of an integrated test program
3. For reliability growth planning use an idealized growth curve (Such as the Duane Model)
4. For reliability growth assessments use demonstrated values (Such as the AMSAA model)
5. Plan for reliability growth to occur only in the developmental parts of the system
6. It is best to track reliability growth at the system level
7. In tracking reliability growth, analyze the data - don't simply "plug and chug"
8. Honest and complete data collection is essential
9. Open reliability forum with membership from both government and contractor should be established to review failures, corrective actions, methods of assessment, etc.
10. Implement fixes to hardware in blocks (i.e., all units should be fixed after sufficient test time has been accumulated to identify failures, corrective actions, etc.)

If properly managed, RGT is an effective method to improve reliability and reduce Life Cycle Costs. In performing RGT it must be understood that it is a process of testing, analyzing failures and implementing fixes. It requires prudent engineering judgement, both technically and economically.

Many thanks to Mr. Walter Lilius of U.S. Army META and the committee members of this year's IES conference on reliability growth management for their inputs.

A PC based implementation of the Duane and AMSAA RGT models is available free of charge from the RAC. The algorithms for each model have been implemented in MatchCad by MathSoft of Cambridge, MA. RAC will send the MathCad templates on a 5 1/4" DD floppy disk in IBM PC format.

For further information regarding Reliability Growth Testing or the MathCad templates contact David F. Tyler, IIT Research Institute, (315) 337-0900.

about an ESD Control program for a large disk file, resolving ESD incidents to spacecraft boards during production and ESD concerns for tape and reel packaging. The Tuesday afternoon session will have presentations on ESD damage threshold testing, latency, photoemission testing GaAs susceptibility effects and bipolar transistor effects with graded collector doping.

Evaluation of materials will be a popular topic in the Wednesday morning papers. Triboelectric properties, worksurface testing, corrosion, and qualification/verification testing of ESD protective materials are to be covered. Wednesday afternoon the evolving techniques for adequately characterizing ESD susceptibility of devices will be presented.

On Wednesday evening, September 28th, five simultaneous workshops have been organized to discuss current topics of high interest: (1) ESD Control requirements in a manufacturing environment, (2) Ionization, (3) System/Subsystem issues, (4) On-Chip protection and (5) ESD failure analysis.

The final technical sessions on Thursday morning will offer attendees a choice between a session on System Level ESD/EMP/EMI Considerations and a session on On-Chip Protection Techniques. Workshops will be held Thursday afternoon.

For entry-level attendees, an all-day Tutorial will be given the day before the Symposium begins.

In retrospect, the EOS/ESD Symposium is a testimony to the concept of technical symposia and what can be accomplished thereby. Through holding annual symposia the awareness and technical understanding of a subject can be enormously expanded. Credit must be given to the visionaries at RADC and RAC who promoted and supported the concept of this symposium.

MRAP/SRAP DISCONTINUED

The May 1988 issue of the Microcircuit Reliability Assessment Program (MRAP) was the final issue. The information in MRAP will be in the newly revised MIL-STD-1562. This document can be obtained by contacting:

DESC/ECS
1507 Wilmington Pike
Dayton, OH 45444-5225
(513) 296-6022 AV: 986-6022

The first NATO Microcircuit Preferred Products List (PPL) has been completed and this information will be reflected in MIL-STD-1562, Revision T, as a basis for reciprocal use of other nations' microcircuits.

The May 1988 issue of the Semiconductor Reliability Assessment Program (SRAP) was the final issue. SRAP users are referred to MIL-STD-701 and "Tabulation of TX & TXV Types Under MIL-S-19500." For information on both of these documents contact.

DESC/ECT
1507 Wilmington Pike
Dayton, OH 45444-5280
(513) 296-5373 AV: 986-5373

CALL FOR PAPERS

The 1989 International Reliability Physics Symposium, to be held 10 - 13 April 1989 in Phoenix, AZ, is seeking papers relevant to building-in and validating reliability for present and developing VLSI and hybrid technologies. Subjects of particular interest are: package design and construction for high reliability, building-in reliability (design and process control for Si and GaAs), analysis for reliability, and test methodologies. Send a one-page, 50-word abstract and a two-page, camera-ready summary to Patrick Kennedy, Hughes Aircraft Co., P.O. Box 3310 B675-C129, Fullerton, CA 92634; Tel.: 714-441-9003; Fax: 714-441-8501. Deadline: Oct. 9, 1988.

NEW RAC PRODUCTS

R, M & S STANDARDS PRIMER: GUIDELINES FOR DoD RELIABILITY, MAINTAINABILITY AND SAFETY STANDARDS

Today's defense contractor is responsible for compliance with a vast array of military specifications, standards and handbooks. It is often difficult to determine those which most adequately address the Reliability, Maintainability and Safety (R, M & S) requirements of a given program without spending a great deal of time, effort and dollars. To simplify this task, the Reliability Analysis Center has published "R, M & S Standards Primer: Guidelines for DoD Reliability, Maintainability and Safety Standards (PRIM-1)."

Each chapter of this 400-page publication deals with a single standard, specification or handbook. It gives a brief description of the document, describes its purpose, explains its significance to the program and/or phase of the program, lists any applicable Data Item Descriptions (DIDs) and gives a brief explanation of how the document should be used. It explains how to tailor the document's requirements and also identifies those documents which may be unique to a specific branch of the military.

PRIM-1 provides the user with a single reference guide to the applicability and use of the most pertinent R, M & S military documents. This publication eliminates the necessity of having to order and review each document separately to determine its applicability to a specific program. This is especially helpful in proposal efforts if the user is not familiar with all of the R, M & S specifications or government procurement programs.

PRIM-1 is available from the Reliability Analysis Center prepaid at $95 U.S. and $115 Non-U.S.

FEEDBACK

RAC MOVE

To our readers:

The RAC has recently moved, although our address and telephone numbers remain the same. As a consequence of the move, we have had difficulty with our (315) 330-4151 line. We apologize for any inconvenience this may have caused. Thank you for your patience.

CALENDAR

Testability Practices Today Training Course, 11-13 October 1988, Syracuse, NY, and 1-3 November 1988, San Jose, CA. Sponsored by the Reliability Analysis Center, P.O. Box 4700, Rome, NY 13440-8200. Contact: Nan Pfrimmer, (315) 337-0900.

Design Reliability Training Course, 24-27 October 1988, Syracuse, NY. Sponsored by the Reliability Analysis Center, P.O. Box 4700, Rome, NY 13440-8200. Contact: Nan Pfrimmer, (315) 337-0900.

Statistical Process Control Training Course, 24-27 October 1988, Syracuse, NY. Sponsored by the Reliability Analysis Center, P.O. Box 4700, Rome, NY 13440-8200. Contact: Nan Pfrimmer, (315) 337-0900.

DTIC'88 Annual Users Conference, 31 October - 4 November 1988, Ramada Hotel - Old Town, Alexandria, VA. For further information about the conference or DTIC's services call: Defense Technical Information Center User Services Branch, (202) 274-3848 or Autovon 284-3848.

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The **RAC NEWSLETTER** is published quarterly and distributed free-of-charge. If you have an article that you would like included in a future newsletter, contact Nan Pfrimmer at the Reliability Analysis Center, P.O. Box 4700, Rome, NY 13440-8200.

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APPENDIX C

USER FEEDBACK LETTERS

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Allied Signal

Bendix Energy Controls Division
[illegible] North Bendix Drive
South Bend, IN 46620

January 14, 1988 Letter No. 862-RER-048

Mr. Steven J. Flint, RAC Technical Director
Reliability Analysis Center
P. O. Box 4700
Rome, New York 13440-8200

Mr. Flint:

I recently received my copy of MDR-22, Microcircuit Screening Analysis and am impressed with the effort. It is an excellent collection of data and a considerable analysis effort. The authors, Chandler, Stockman and Denson are to be commended on some interesting and exhaustive work. It must have taken quite a while to assemble it and even figure out how to analyze it. In particular, I like the data presentation in the appendix. However, there were several pages on which I have some questions. These are listed below.

PAGE	COMMENT OR QUESTION
2-3	There seems to be an error in the Fall Out Rate Equation. Shouldn't it be: # Failed divided by # Tested?
2-25 thru 2-28	Were the rescreening test levels commensurate with the labeled quality class of the ICs? Or were the rescreening tests essentially the same for all classes. I find it most interesting that the "B" class group had a markedly higher fallout than the "D" class which is supposedly of a lower quality.
2-65	Why was no regression analysis shown of the Burn-In data against "Screen Type"? This would be very useful information regarding the actual quality of the various class types as they left the assembly process.
2-94	Same comments on rescreening versus class level as on pages 2-25 thru 2-28
2-105	The conclusions drawn in the last paragraph that "Stabilization bake and temperature cycle have higher fall-out rates than does thermal shock. Also for the data observed,....." are not supported by either Figure 38, or the data shown in Table 20.
A-6	In the fourth paragraph, the second sentence starting "Thermal shock...." seems to be missing something. In the fifth paragraph, the last sentence starting "In general, ..." seems to be missing something.
A-12	The second paragraph under the X-Ray section seems to be more general than just X-Rays and probably should be at the beginning of the appendix.

Mr. Steven Flint January 14, 1988

If one or more of the authors would like to discuss these comments with me, they can reach me at (219)237-2239 from 7:30 a.m. to 4:30 p.m. EST, Monday through Friday. In particular, I am concerned about the lack of major conclusions or analysis of fall out relative to device quality class.

Thank you,

Robert E. Raymond
Electronic Controls Engineering

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of
Rome Air Development Center

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